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Growth And Flowering Of Chrysanthemum Basal Shoot Cuttings In Response To Rootone-F Concentration And Soaking Duration

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ABSTRACT

Chrysanthemum is an ornamental crop whose production depends on reliable planting materials. This study evaluated the effects of Rootone-F concentration and soaking duration on the growth and flowering of basal shoot cuttings. A factorial randomized block experiment was conducted from May to August 2023 at Universitas Borneo Tarakan, Indonesia, with four nominal Rootone-F levels (0, 0.1, 0.2, and 0.3 mL L^{-1}), four soaking durations (10, 20, 30, and 40 minutes), and two blocks, giving 32 experimental units. Eight vegetative, root, and flowering traits were assessed. Under the stated design, the tabulated F values support a soaking-duration effect on plant height at 12 weeks after planting and concentration and interaction effects on productive branch number at 8 weeks. They do not support soaking-duration effects on leaf number or productive branch number at the 5% level. The combination of 0.1 mL L^{-1} and 30 minutes had the highest numerical productive branch mean (2.30 per plant), but the displayed mean-separation groups overlap with other combinations. Most traits showed no statistically detectable treatment response. Limited replication and incomplete treatment-preparation details restrict interpretation; the findings do not establish an optimal propagation protocol.

INTRODUCTION

Chrysanthemum belongs to the Asteraceae and is cultivated for diverse ornamental flower forms [1,2]. Its uses include cut flowers and potted plants, and its cultivation can contribute to grower income [3]. Reliable production requires healthy, uniform planting materials as well as appropriate cultivation practices [4].Local propagation methods are relevant to the development of chrysanthemum production in Indonesia [5–8]. Vegetative propagation can multiply selected mother plants while retaining clonal characteristics. Basal shoot cuttings offer a practical source of planting material, provided that the mother plants are healthy and suitable shoots are available. For a propagation treatment to be useful, its response must be evaluated against a water-treated control as well as against other application levels. A treatment that increases one trait does not necessarily improve the complete production sequence. Root development, shoot establishment and flowering represent related but distinct outcomes, and their separate assessment is needed to determine the scope of any apparent benefit. This distinction is particularly relevant when the propagation material already has the capacity to establish without an external rooting preparation.

The establishment of cuttings depends on adventitious rooting, which supports water and nutrient uptake [9,10]. Cutting condition, growing medium, and environmental conditions influence establishment [11]. Responses to propagation treatments differ among species and cutting types [12]. Nutrient and medium management can also influence vegetative propagation performance [13].Rootone-F is a commercial rooting preparation used in cutting propagation studies [14]. Responses have been investigated in jabon [15], Begonia tuberosa [16], red betel [17], pule pandak [18], and fig [19]. These responses cannot be generalized directly to chrysanthemum because plant material and application procedures differ. Product formulation, concentration, and exposure duration must therefore be specified when comparing treatments. Basal shoot material also

provides a specific context for evaluating treatment effects. Results obtained with another cutting source cannot determine the response of this material because tissue condition and developmental stage may differ. Similarly, a product concentration cannot be interpreted independently of the way it is prepared and applied. Reporting both concentration and duration is therefore necessary for a treatment comparison to be interpretable and, ultimately, repeatable by other researchers.

Root development and subsequent flowering are both relevant to chrysanthemum propagation. Studies have evaluated rooting treatments and biological approaches in chrysanthemum [20,21]. Flower initiation and development also depend on photoperiod and temperature [22,23]. Consequently, flowering differences following an early rooting treatment should be interpreted in relation to the growing environment. The practical question is whether these treatment factors produce a consistent improvement across the traits that matter for ornamental production. A factorial comparison addresses the possibility that a given concentration performs differently at different immersion durations. At the same time, numerical maxima require careful interpretation: the largest observed mean alone does not establish superiority, and an isolated response should be considered alongside the performance of untreated plants and the uncertainty of the experiment.

Previous chrysanthemum propagation studies have considered cutting characteristics, rooting treatments, and immersion time [24,25]. The combined effects of Rootone-F concentration and soaking duration on basal shoot establishment and subsequent flowering under Tarakan growing conditions require further evaluation. A factorial experiment can assess whether concentration responses depend on soaking duration.

Therefore, this study aimed to evaluate the effects of Rootone-F concentration, soaking duration, and their interaction on the growth and flowering of chrysanthemum basal shoot cuttings. The study examined vegetative growth, root characteristics, branch development, and flower production under the tested treatment conditions. It was hypothesised that Rootone-F concentration, soaking duration, and their interaction would influence one or more of these parameters. The findings are expected to provide preliminary information for assessing the suitability of Rootone-F application in chrysanthemum propagation, particularly under the growing conditions of North Kalimantan.

MATERIALS AND METHODS

Study Site and Plant Materials

The experiment was conducted from May to August 2023 at the experimental field of the Faculty of Agriculture, Universitas Borneo Tarakan, North Kalimantan, Indonesia. Materials included chrysanthemum basal shoot cuttings, Rootone-F, water, soil, chicken manure, NPK fertilizer, and polybags. Equipment included soil-preparation tools, a cutter, watering can, weighing scale, net, ruler, and camera.

Basal shoots were collected from healthy chrysanthemum mother plants with high flower productivity and no visible pest or disease symptoms. The growing area was cleared of weeds, and the soil was loosened, sun-dried for one week, and sieved. The soil was mixed with 1 kg of chicken manure as basal fertilizer and incubated for one week. The growing medium was then placed in polybags containing 5 kg of soil per polybag.

Experimental design and Treatments

The experiment was arranged in a factorial randomized block design (RBD) consisting of two factors. The first factor was Rootone-F concentration, comprising four levels: 0 mL L^{-1} (R0), 0.1 mL L^{-1} (R1), 0.2 mL L^{-1} (R2), and 0.3 mL L^{-1} (R3). The second factor was soaking duration, comprising four levels: 10 min (P1), 20 min (P2), 30 min (P3), and 40 min (P4). The combination of the two factors resulted in 16 treatment combinations, with two replications, giving a total of 32 experimental units. The control cuttings were soaked in water for the corresponding treatment durations.

Planting Material Preparation and Maintenance

Basal shoot cuttings were obtained from healthy, productive mother plants without visible pest or disease symptoms. Cuttings were immersed in their assigned Rootone-F treatments; controls were immersed in water for the corresponding durations. Dead plants were replaced with spare seedlings during maintenance. Such replacement can affect comparisons if plants differ in age or treatment history and is a limitation of the experiment.

Rootone-F Application and Crop Maintenance

Rootone-F treatments were designated by nominal concentrations of 0, 0.1, 0.2, and 0.3 mL L^{-1}. These nominal units do not establish the powder mass or active-ingredient dose per litre and should not be equated with mg L^{-1}. Cuttings were immersed for their assigned durations in the morning and planted. Seedlings were transferred to treatment polybags after rooting and developing approximately two leaves, about 14 days after planting. Watering was conducted in the morning or evening according to medium

conditions and omitted during rainfall. Weeds were removed manually, followed by earthing up. Decis insecticide (2 mL L^{-1}) and Dithane M-45 fungicide (2 g L^{-1}) were used for crop protection. Dead or abnormal plants were replaced with spare seedlings.

Observations

Plant height (cm), number of fully opened leaves, and number of basal shoots were recorded at 2, 4, 6, 8, 10, and 12 weeks after planting (WAP). Plant height was measured from the soil surface to the highest growing point. Root number and root length (cm), measured from the base to the root tip, were recorded at 12 WAP when the plants were uprooted. The number of branches and productive branches was recorded at 8 WAP, while the number of flowers on the main stem was recorded at 12 WAP. Productive branches were defined as branches bearing flowers, whether open or unopened.

Data Analysis

Experimental-unit means were used for analysis of the factorial randomized block design. The model includes block, Rootone-F concentration, soaking duration, their interaction, and residual error. With 32 complete experimental units and two blocks, concentration and duration each have 3 degrees of freedom, their interaction has 9, and residual error has 15. At a 5% significance level, the corresponding critical F values are approximately 3.29 for main effects and 2.59 for the interaction. Table 1 interprets the tabulated F values using these degrees of freedom. Duncan's multiple range test (DMRT) was used for mean separation. The grouping letters in Tables 2 and 3 are retained as descriptive outputs of that procedure; their validity depends on the original error term and comparison scheme. The endpoint tests are exploratory because several traits and observation times were assessed.

Conceptual Framework

The availability of healthy, uniform, and sustainable chrysanthemum planting materials remains a challenge for local cultivation in Tarakan, North Kalimantan. Vegetative propagation using basal shoot cuttings offers a practical approach to producing planting materials, while the application of Rootone-F may influence rooting and subsequent plant development. This study evaluates two independent variables: Rootone-F concentration (0, 0.1, 0.2, and 0.3 mL L^{-1}) and soaking duration (10, 20, 30, and 40 minutes), including their individual effects and interaction (Figure 1).

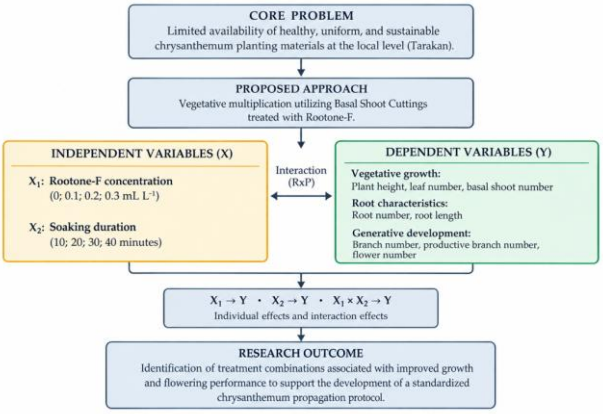


Figure 1. Conceptual framework illustrating the effects of Rootone-F concentration and soaking duration on the growth and flowering of chrysanthemum basal shoot cuttings.

The dependent variables include vegetative growth (plant height, leaf number, and basal shoot number), root characteristics (root number and root length), and generative development (branch number, productive branch number, and flower number). The study employs a factorial randomized block design to evaluate the individual effects of Rootone-F concentration and soaking duration, as well as their interaction. The results are expected to provide preliminary evidence for identifying treatment combinations that may improve the growth and flowering performance of chrysanthemum basal shoot cuttings under local growing conditions.

RESULTS

For the stated two-block design, the F values in Table 1 indicate a soaking-duration effect on plant height at 12 WAP and concentration and interaction effects on productive branch number at 8 WAP. The F values for soaking effects on leaf number (3.117) and productive branch number (2.970) are below the main-effect critical value of approximately 3.29. Most other endpoint tests show no statistically detectable treatment response.

Table 1. F values from the analysis of variance for the effects of

Parameter	Rootone-F (R)	Soaking duration (P)	Interaction (R×P)
Plant height 12 WAP	1.922 ns	3.351 *	1.372 ns
Number of leaves 12 WAP	0.929 ns	3.117 ns	1.569 ns
Number of basal shoots 12 WAP	0.845 ns	0.603 ns	0.953 ns
Root number 12 WAP	0.450 ns	0.757 ns	0.582 ns
Root length 12 WAP	0.611 ns	1.133 ns	0.579 ns
Number of branches 8 WAP	1.468 ns	0.498 ns	0.511 ns
Number of productive branches 8 WAP	5.394 *	2.970 ns	3.333 *
Number of flowers on main stem 12 WAP	0.519 ns	1.102 ns	0.466 ns

Rootone-F concentration and soaking duration on the growth and flowering of chrysanthemum basal shoot cuttings

Note: * = F exceeds the 5% critical value for the stated design; ns = F does not exceed that value. Main effects: df = 3, 15; interaction: df = 9, 15. Critical F values are approximately 3.29 and 2.59, respectively. These classifications depend on the stated experimental-unit structure. WAP = weeks after planting.

Parameter	R0	R1	R2	R3	P1	P2	P3	P4
Plant height 12 WAP (cm)	36.33	34.99	29.00	38.33	43.16	34.16	27.99	33.33
Number of leaves 12 WAP	35.66	33.50	40.50	40.33	42.16	44.16	29.83	33.83
Number of basal shoots 12 WAP	4.83	3.16	4.33	4.00	5.00	3.50	3.33	4.50
Root number 12 WAP	29.72	27.10	29.33	31.83	29.55	32.33	27.60	28.49
Root length 12 WAP (cm)	10.16	10.33	9.27	11.49	10.50	11.00	11.05	8.72
Number of branches 8 WAP	3.33	3.00	3.11	3.38	2.77	4.11	2.50	3.44
Number of productive branches 8 WAP	1.43 bc	1.63 c	1.11 a	1.31 ab	1.23 a	1.59 b	1.40 ab	1.26 a
Number of flowers on main stem 12 WAP	1.39	1.16	1.55	1.89	3.00	2.22	0.78	0.00

Descriptively, the 10-minute soaking duration consistently yielded the highest mean plant height from 2 to 12 WAP. On the contrary, the 30-minute soaking duration resulted in the lowest plant height throughout the entire evaluation period. The remaining soaking durations of 20 and 40 minutes exhibited intermediate and closely overlapping growth patterns (Figure 2).

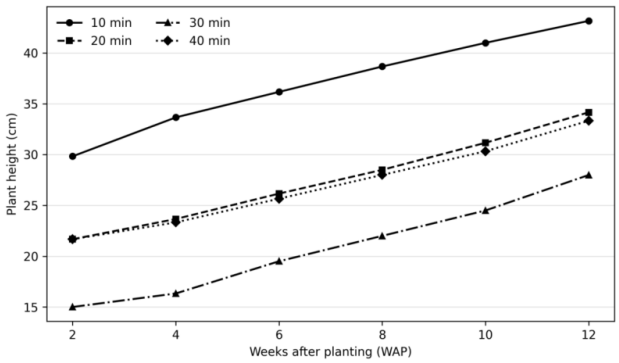


Figure 2. Descriptive plant-height means across soaking durations from 2 to 12 weeks after planting (WAP), averaged over the four nominal Rootone-F levels. Line separation does not establish statistical differences. Variability estimates are not displayed.

At 12 WAP, plant height ranged from 22.66 to 51.33 cm and leaf number from 24.00 to 53.33 across treatment combinations. The soaking-duration means for plant height ranged from 27.99 cm (30 minutes) to 43.16 cm (10 minutes). Leaf number ranged from 29.83 (30 minutes) to 44.16 (20 minutes) across soaking levels, but its F value does not meet the 5% main-effect threshold for the stated design. Rootone-F concentration and the interaction did not show significant effects on either trait. R3P4 had the highest numerical plant height (51.33 cm), and R2P2 the highest numerical leaf number (53.33). These combinations cannot be ranked as statistically superior from the nonsignificant interaction tests. Basal shoot number (2.66–6.00), root number (17.55–36.44), and root length (6.00–14.66 cm) also showed no statistically detectable treatment effects. Mean root numbers were 29.72 for R0 and 31.83 for R3.

Table 2. Mean growth and flowering parameters of chrysanthemum basal shoot cuttings by Rootone-F concentration and soaking duration

Note: R0 = water control; R1 = 0.1, R2 = 0.2, and R3 = 0.3 nominal mL L^{-1} Rootone-F. P1 = 10, P2 = 20, P3 = 30, and P4 = 40 minutes. WAP = weeks after planting. Productive-branch letters reproduce the DMRT grouping; shared letters denote overlapping groups within a factor. Because interaction is significant, marginal means do not establish an overall concentration or duration ranking.

Branch number at 8 WAP showed no statistically detectable treatment effects. Productive branch number showed concentration and interaction effects under the stated design; the soaking main effect did not meet the 5% threshold. R1P3 had the highest numerical mean (2.30 productive branches per plant). Its letter group (d)

overlaps with R0P2 (1.80, bcd) and R3P2 (1.95, cd); it is therefore not uniquely superior under the displayed DMRT grouping (Table 3).

Table 3. Mean number of productive branches at 8 WAP by the interaction of Rootone-F concentration and soaking duration

Soaking duration	R0	R1	R2	R3
P1 (10 minutes)	1.30 ab	1.45 abc	1.15 a	1.00 a
P2 (20 minutes)	1.80 bcd	1.45 abc	1.15 a	1.95 cd
P3 (30 minutes)	1.15 a	2.30 d	1.00 a	1.15 a
P4 (40 minutes)	1.45 abc	1.30 ab	1.15 a	1.15 a

Note: Shared letters indicate overlapping DMRT groups at the 5% level. The letters do not support a significant difference between R1P3 and every other combination. Treatment codes are defined in Table 2. The comparison family and error term require confirmation before the groupings can support final treatment recommendations.

Flower number on the main stem at 12 WAP showed no statistically detectable treatment effects (Table 1). Mean counts across soaking durations were 3.00, 2.22, 0.78, and 0.00 for 10, 20, 30, and 40 minutes, respectively (Table 2). R3P1 had the highest numerical combination mean (6.22). These descriptive differences do not establish a treatment-related decline in flowering.

Only two independent blocks were included. This limits precision and makes the results sensitive to between-unit variability. The absence of significant effects does not demonstrate equivalence between treated and control plants. Additional independent replication would improve estimation of treatment effects and their uncertainty.

The endpoint root measurements showed no statistically detectable response. Early root initiation, rooting percentage, endogenous hormone concentrations, and treatment-related physiological stress were not measured. Rooting mechanisms and the relative contributions of medium and microclimate therefore remain unresolved.

DISCUSSION

Vegetative growth.

Rootone-F concentration did not significantly affect most vegetative growth parameters of chrysanthemum basal shoot cuttings under the conditions of this study. This indicates that the tested concentrations did not produce a statistically detectable improvement in the measured growth traits. The response may vary depending on plant species, cutting characteristics, auxin concentration, and growing conditions. However, the present study did not measure endogenous hormone levels; therefore, the contribution of endogenous auxin to the observed response remains a possible explanation rather than a confirmed mechanism.

The soaking response was not proportional to exposure duration. Plant height showed a detectable duration effect at 12 WAP, whereas the leaf-number F value did not exceed the threshold for the stated design. Pairwise differences in plant height require a valid follow-up comparison rather than a ranking based only on mean values.

Endogenous auxin status is one possible explanation for weak responses to exogenous rooting products, given the hormonal regulation of adventitious roots [26,27]. However, hormone concentrations were not measured. Similar control and treated root counts do not establish hormonal saturation or maximum rooting capacity. Evidence from coffee cuttings also illustrates the importance of genotype and trait-specific responses [28], without demonstrating the same mechanism in chrysanthemum.

Rootone-F responses reported for Begonia tuberosa [16] and cajuput [29] provide comparative context, but differences in species, cutting type, and application conditions limit transfer of those results. In particular, nominal mL L^{-1} levels cannot be compared directly with powder concentrations expressed in mg L^{-1} without a defined stock preparation.

Flowering

The productive-branch response suggests that concentration effects may depend on soaking duration. However, the highest numerical combination overlaps with other DMRT groups, and most measured traits showed no interaction. The result is exploratory and requires confirmation with more independent blocks, appropriate simple-effect comparisons, and uncertainty estimates.

Flower number showed no statistically detectable treatment effect. Photoperiod and temperature are established influences on chrysanthemum flower development [22,23,30], but the experiment does not show that these factors caused or masked treatment responses. The descriptive decline across soaking durations cannot be interpreted as evidence of toxicity or delayed flowering.

Future experiments should record time to flower initiation and opening, distinguish buds from open inflorescences, and document day length, temperature, and cultivar identity. These measurements would help distinguish early propagation responses from later environmental influences.

Cultivar morphology and growing conditions are relevant to ornamental performance [2,3]. Post-harvest evidence from other ornamentals [31] concerns a separate production stage and does not establish the

mechanism of the present chrysanthemum branching response.

The tested Rootone-F levels did not produce a consistent improvement across vegetative, root, and flowering traits. These results apply to the nominal treatments and conditions examined. An economic recommendation requires treatment-cost information and a more precise estimate of agronomic benefit.

For application in local propagation, the central issue is reproducibility rather than selection of the largest mean. A useful follow-up comparison should preserve a water-treated control, define the amount of commercial product per unit volume, and retain the experimental unit as the level of replication. Recording plant replacement and establishment would also help distinguish growth of surviving plants from overall propagation success. These steps would allow a subsequent trial to evaluate whether an apparent branching response is stable across blocks and whether it is accompanied by useful root or flower responses. Until that evidence is available, the present findings provide a bounded comparison of the tested treatments rather than a standardized recommendation for growers.

CONCLUSION

Under the stated factorial randomized block design, the tabulated F values support a soaking-duration effect on plant height at 12 WAP and concentration and interaction effects on productive branch number at 8 WAP. They do not support soaking main effects on leaf number or productive branch number at the 5% level. R1P3 (nominal 0.1 mL L^{-1}, 30 minutes) had the highest numerical productive branch mean (2.30 per plant), but it was not uniquely superior under the displayed overlapping groups. Most traits showed no statistically detectable treatment response. Two-block replication, uncertain dose specification, and plant replacement limit generalization. The results do not establish an optimal treatment or a general economic advantage for Rootone-F.

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