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Research Article

Effect of Seed Pelleting Application on Germination and Growth of *Celosia Cristata*

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Abstract

The objective of this study was to study the effect of pelleting technology on seed quality and lifetime of Celosia cristata. This study utilized cockscomb 'Century' as the experimental material and established three treatments: naked seeds, seeds treated with a basic pellet formulation, and seeds treated with a basic pellet formulation supplemented with biochar. Pelleting treatments significantly enhanced seed germination and seedling development. Specifically, the basic pellet formulation resulted in earlier seedling emergence in tray-sown cockscomb seeds. Additionally, it contributed to increased shoot length, as well as improved seedling length and dry weight. Seeds pelleted with biochar formulation resulted in shortened Mean Emergence Time (MET) and increased shoot length, crown diameter, main stem diameter and Soil-Plant Analyses Development (SPAD) index (chlorophyll measurement). This study provides technical support for the application of seed pelleting in the tray seeding production and direct field sowing of cockscomb.

Keywords: *Celosia cristata*; Seed pelleting; Biochar; Seed quality inspection; Growth index

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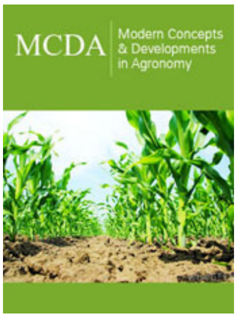

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Introduction

Seeds of some herbaceous ornamental plants are extremely tiny, with uneven size, irregular shape and strong fluidity, which cause difficulties such as excessive seeding, low germination rate and seeding holes clogging during mechanical sowing. Seed pelleting can significantly increase the volume and weight of herbaceous plants seeds, making the seed more regular and uniform, and more suitable for mechanical sowing. Cockscomb *(Celosia cristata L.)* is an ornamental plant deeply loved by people all over the world, it could be cultivated easily and widely applied as potted plants, flower beds, flower clusters, flower borders, flower seas or fresh cut flowers for decoration [1]. However, the seeds of cockscomb are extremely tiny, black, with a thousand-grain weight of approximately 1.5g. The precise sowing of small seeds is difficult and labor-intensive [2]. Seed pelleting technology is one type of seed coating to combine fillers with seeds through mechanical processing, forming seeds with uniform shape (usually being a spherical shape), plump grains and smooth surface [3,4], pelleted seeds have increased weight and volume which effectively solve the clogging problem in mechanical sowing and facilitate precise sowing and large-scale seedling production to reduce production costs. Besides, pelleted seeds have an increased ability to absorb water and oxygen, thereby improving the germination rate [5]. In addition, insecticides, fungicides, micronutrients, growth regulators, trace elements, dyes and other substances can be incorporated into the pellet filler to enhance seed quality, germination and development, make seeds suitable for mechanical sowing and long-distance transport, promote seedling growth, prevent diseases and pests, enhance seed stress tolerance and ameliorate soil conditions [6,7].

Seed pelleting technology not only addresses the pain points of conventional sowing but also drives the floriculture industry toward precision, mechanization, and sustainability. Although most flower seeds in Dutch are already pelleted for commercial production [8], the exact formulations remain trade secrets and are rarely reported in the literature. Moreover, few seeds pelleting formulation for ornamental plants are available in China and none have yet been developed for cockscomb seeds. The foremost challenge in flower-seed pelleting is to design formulations and processes according to characteristics of different plants to improve their sowing performance [9]. Therefore, developing an effective pelleting formulation for cockscomb is of critical importance. Biochar refers to carbon-rich particles produced by the pyrolysis of biomass, such as agricultural and forestry residues like straw, grass, wood chips and livestock manure, under conditions of incomplete combustion or oxygen deficiency [10]. Multiple studies have shown that due to its high porosity and high concentrations of organic matter and nutrients, biochar can promote the proliferation of beneficial microorganisms around plant roots, improve soil physical and chemical properties, create a favorable growth environment for seedlings of vegetables and crops such as rapeseed, pakchoi and tea, thereby facilitating plant growth [11-15]. In this study, biochar was used as the promoting substance in pellet formulation to evaluate the performance differences between the basic pellet formulation and the formulation with added biochar, and to explore the effect of biochar-based pellet on the quality of cockscomb seeds.

Material and Methods

Pelleting cockscomb seeds

Select cockscomb 'Century' seeds that are plump in shape and uniform in size. Two types of pellet filler were prepared, one is the basic pellet formulation (R6) with a weight ratio of concave-convex rod: talc powder: diatomite=6:2:2 [16], the other is composite formulation CR6 with a weight ratio of basic pellet formulation (R6): biochar=7:3. Weigh a certain amount of naked cockscomb seeds and weigh the pellet filler with 2 times the weight of naked seeds. An 1.5% (w/v) polyvinyl alcohol (Hushi, Shanghai, China) was prepared as the pelleting binding agent to keep the seed surface moist and non-sticky. Place the seeds and two-fifths of the pellet filler into the rotary drum (BY-300A, HUANGHAI, China) which was operated at 80 revolutions per minute (rpm), During this process, keep stirring the seeds with hands to achieving a state in which the seeds are even and non-sticky, then pour the seeds into a suitably sized mesh sieve. After sieving, seeds with a single layer of pellet filler are obtained. Seeds and two-fifths of the pellet filler were added into the rotary drum again, rotate the machine for 8 minutes, then pour the seeds into the mesh sieve again and discard the residual filler. Repeat the above steps once with the left one-fifths pellet filler. After rotating for 2 minutes, preliminary pelleted seeds were obtained. Seeds were left at room temperature to reduce the seed moisture to 7% and then kept for later use.

Evaluation of seed quality

According to the Xinjiang Standard Pelleted Seed of Tomato (DB65/T 3031-2009) [17], the quality of the pelleted seeds was assessed through the following procedures. Seed retention rate and single-seed rate: For each treatment, 50 pelleted seeds are selected, use tweezers to remove the pelleted powder and observe the number of seeds in each pelleted seed. Pelleting multiple: Take 100 naked seeds and 100 pelleted seeds and weigh them using a balance accurate to one-thousandth of a gram. Cracking rate: Select 50 pelleted seeds and place them evenly in a germination box (120×120×60mm, L×W×H), add 25mL of distilled water to submerge the seeds. After 5 minutes, observe the disintegration status. If the seeds can be easily dispersed with a gentle prod from tweezers, they are considered to have disintegrated. The uniformity test was conducted on 5g pelleted seeds per treatment using 2mm and 3mm mesh sieve, weighing the seeds with standard particle size (2-3mm). Percent uniformity was determined by the following formula: % Pelleted seeds uniformity=(weight of seeds with standard particle size/weight of 5g seeds) *100. There were three replicates per treatment.

Germination testing of pelleted seeds under laboratory conditions

50 seeds per treatment were sown in the germination box on 3 pieces of filter paper moistened with distilled water. Observe the moisture level of the filter paper in the germination box daily. Depending on the condition, add 2mL of distilled water to each corner of the germination box to maintain the moisture of the filter paper. If mold is found on the filter paper or seeds, replace the germination box and filter paper in time. The cultivation condition was 20 ℃ 16h 0lx/15 ℃ 8h 0lx. Calculate the germination and emergence rates daily. When the number of germinated seeds no longer increases, transfer the seedlings to the second stage of cultivation under light conditions 17 ℃ 16h 13000lx/15 ℃ 8h 0lx. The testing protocols adhered to the guidelines outlined by the International Seed Testing Association [18]. Germination rate, emergency rate, Mean Germination Time (MGT), Mean Emergency Time (MET), Seedling Vigor Index (SVI), Germination Index (GI), germination energy, stem length, root length, seedling height, Dry Weight (DW) of stem, root and seeding were determined.

Plug tray sowing testing

The seedling substrate formulation was imported peat moss: perlite: vermiculite=8:3:3. Before sowing, the substrate in the plug trays was thoroughly watered with a 1000-fold dilution of 75% chlorothalonil solution. 50 seeds per treatment were sown in the 50-cell plug tray respectively. When the root had developed sufficiently to firmly hold the substrate, the seedlings were removed from the greenhouse and transplanted into a fertile, well-leveled and well-drained experimental field. The seedlings were planted at a spacing of 30cm between plants and rows. One week after transplanting, the number of surviving plants was recorded for each treatment, with three replicates. Data for various indicators were documented.

Field direct sowing testing of pelleted seeds

The substrate soil added with organic fertilizer and compound fertilizer was leveled in advance before the field direct sowing testing was conducted in autumn 2024. 100 seeds per treatment were sown by hand with a row spacing 25cm and a plant spacing 25cm, with three replicates. Two sowing schemes were set up. Scheme A: one seed per hole; Scheme B: two seeds per hole. After sowing, seeds were covered with a thin layer of vermiculite and then watered thoroughly. A low concentration balanced liquid fertilizer was applied once a week. Data for various indicators were documented. The experiment was conducted at the ornamental plant base of Huazhong Agricultural University, located in Wuhan, Hubei Province, China (114°21′59″E 30°28′36″N).

Data processing

Experimental data were organized and analyzed using Microsoft Excel 2021. Laboratory and field treatments were arranged in a complete randomized plot design and the data collected were Analyzed by One-Way Analysis of Variance (ANOVA). Difference between treatments was tested by Duncan's New Multiple Range Test (DMRT).

Result

Pelleted seed quality testing

The seed quality of pelleted cockscomb seeds was tested. The results showed that the seed weight of R6 formulation increased to 3.79 times that of naked seed control (CK), while the seed weight of CR6 formulation increased to 3.1 times that of CK. Pelleting significantly increased the weight and volume of the seeds, with a notable pelleting effect (Table 1, Figure 1). The seed cracking rate of both pellet formulations reached 100%. Compared with R6, the seeds of CR6 formulation had a higher seed retention rate and single-seed rate.

Table 1: Quality evaluation of cockscomb pelleted seeds.

Quality Index	CK	R6	CR6
Pelleting multiple	1.00±0.00 c	3.79±0.27 a	3.10±0.18 b
Seed retention rate		94%±2%	99%±1%
Single-seed rate		89%±4%	93%±1%
Cracking rate		100%±0%	100%±0%
Uniformity		66%±2%	62%±4%

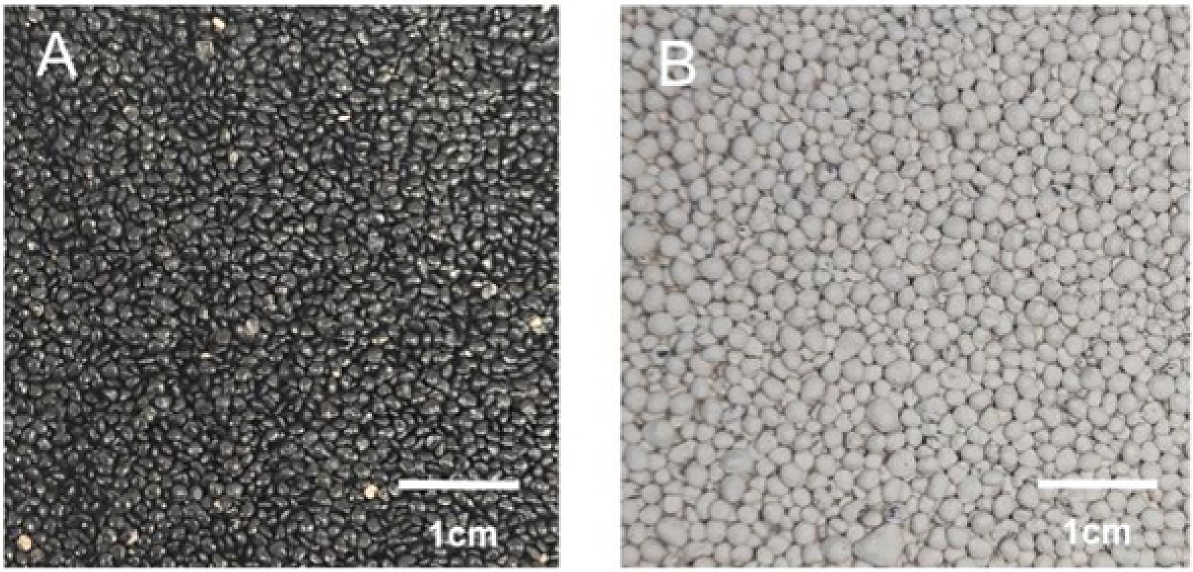

Figure 1: Comparison of cockscomb seeds before and after pelleting.
A) The naked seeds of cockscomb; B) Cockscomb seeds pelleted with formulation R6.

Effect of pelleting cockscomb seeds under laboratory condition

Under laboratory conditions, both R6 and CR6 formulation significantly enhanced stem length, root length, seedling length, seedling dry weight and seedling vigor index of cockscomb seedlings, while markedly shortening the mean emergence time. Compared with CK, R6 and CR6 increased seedling length by 22.77% and 42.96%, raised seedling dry weight by 35.42% and 39.58%, and improved seedling vigor index by 25.32% and 49.11%, respectively (Figure 2). With respect to emergence rate, germination potential and germination index, neither R6 nor CR6 had any significant negative effect on germination potential, however, CR6 significantly elevated germination rate and germination index relative to CK. Overall, the R6 formulation exerted a certain promotive effect on seed germination and seedling growth of cockscomb without any significant adverse effects on other parameters. The CR6 formulation performed even better, providing a marked stimulatory effect on both seed germination and seedling growth of cockscomb.

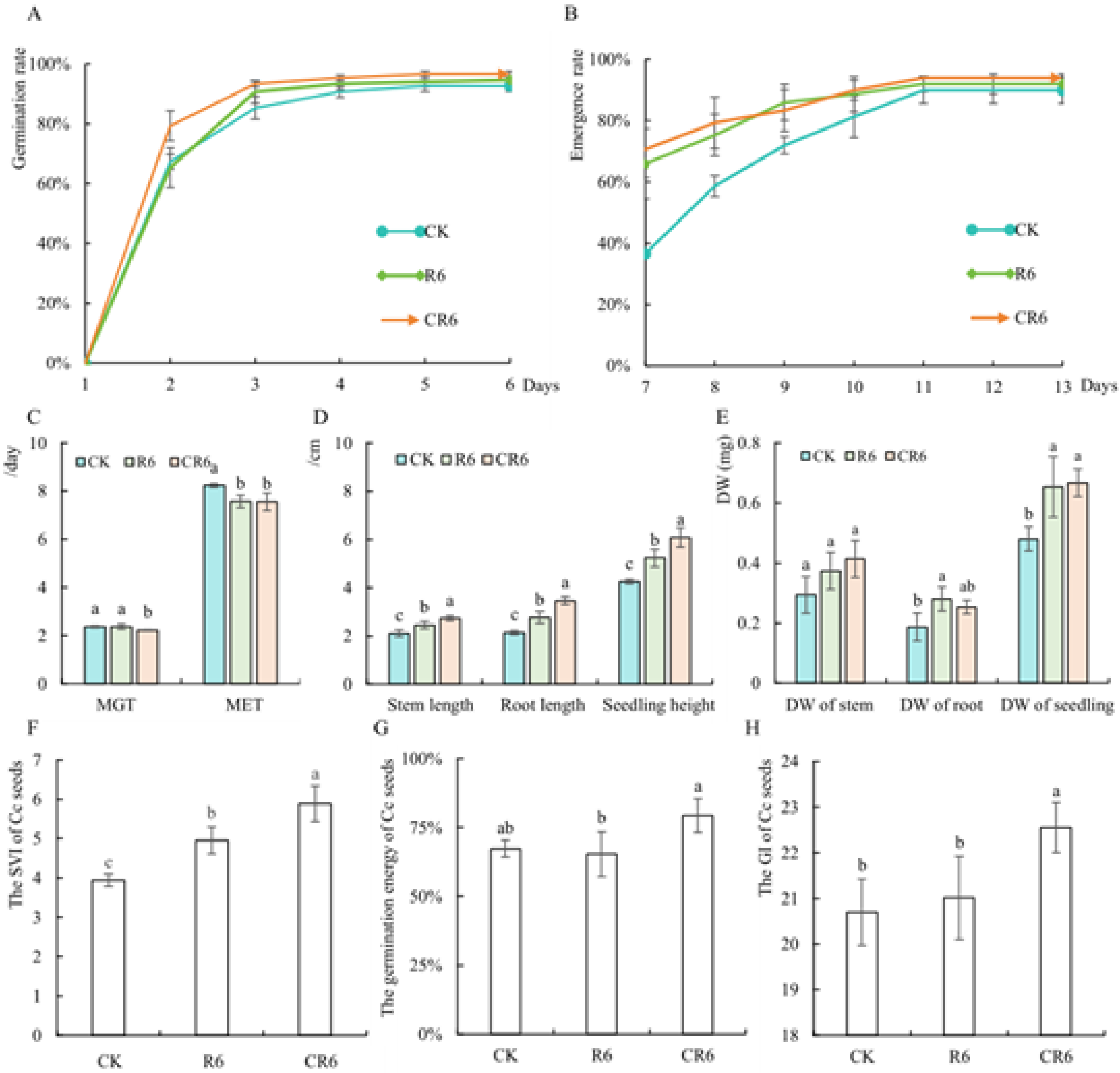

Figure 2: Effect of pelleting treatment on cockscomb seeds in controlled indoor germination experiment.
A) The germination rate of cockscomb seeds; B) The emergence rate of cockscomb seeds; C) The MGT and the MET of cockscomb seeds; D) The stem length, root length, and seedling height of cockscomb; E) The stem dry weight (DW), root dry weight, and seeding dry weight of cockscomb; F) The seedling vigor index (SVI) of cockscomb; G) The germination energy of cockscomb seeds; H) The germination index (GI) of cockscomb seeds.
The relevant seedling data were measured on the 14th day after sowing. Results are presented as mean ±SD, one-way ANOVA and Duncan test were used; n=3; different lowercase letters indicate significant differences between treatments ($P<0.05$).

Effect of pelleting cockscomb seeds in plug tray sowing

Compared with CK, both R6 and CR6 significantly shortened the mean emergence time and increased shoot length of cockscomb seedlings. The mean emergence time was reduced by 0.55d and 1.17d with R6 and CR6, respectively, while shoot length rose by 13.40% and 33.83% (Table 2, Figure 3); CR6 exerted a more pronounced promotive effect on both parameters. For crown diameter, days from sowing to flowering, main stem diameter and leaf chlorophyll content, R6 showed no significant adverse effects relative to CK. CR6, however, significantly increased crown diameter (by 14.62%), main stem diameter and leaf chlorophyll content, but delayed flowering by 11.56% (Table 2). Neither R6 nor CR6 differed significantly from CK for emergence rate, transplant survival rate, flowering earliness, flower size or flowers per plant, indicating no negative impact. In summary, R6 advanced plug-tray emergence and improved shoot length without any significant negative effects on other traits. CR6 further accelerated emergence and markedly enhanced shoot length, crown diameter, main stem diameter and leaf chlorophyll content, demonstrating a clear promotive effect on seed germination and plant growth of cockscomb.

Table 2: Growth and morphological traits of cockscomb in the plug tray seeding experiment.

Treatment	CK	R6	CR6
MET	6.81±0.14a	6.26±0.13b	5.64±0.24c
The survival rate of transplanting	93.52±1.60a	97.22±4.81a	99.07±1.60a
Shoot length	32.46±1.61c	36.81±1.82b	43.44±1.89a
Crown diameter	33.51±1.26b	33.38±1.02b	38.41±1.98a
Flower diameter	10.18±0.19a	10.32±0.45a	10.80±0.66a
Main stem diameter	4.10±0.07b	4.31±0.13ab	4.38±0.13a
Flower number per Plant	9.07±0.68a	9.80±0.13a	9.80±0.13a
Leaf SPAD	21.09±0.63b	21.95±0.25ab	22.53±0.52a
Days from sowing to flowering	75.00±2.00b	76.33±0.58b	83.67±1.15a

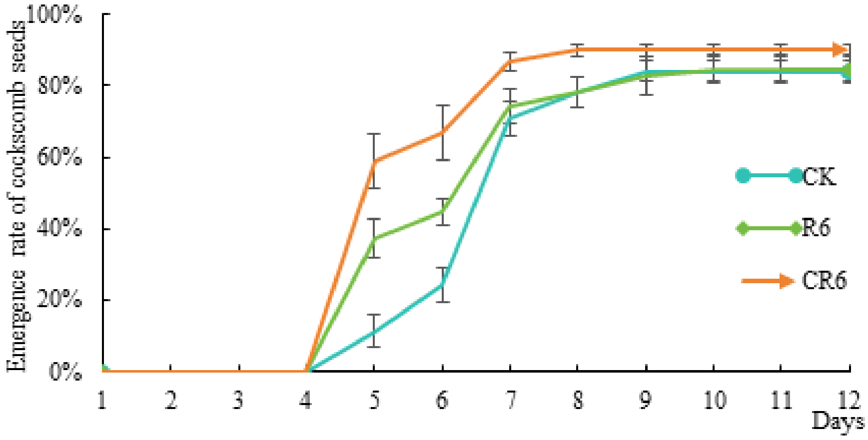

Figure 3: The emergence rate of cockscomb seeds in the plug tray seeding experiment.

]Effect of pelleting cockscomb seeds in field direct sowing

Under sowing scheme, A, emergence rate with R6 did not differ significantly from CK, whereas that with CR6 was reduced (Figure 4A). In contrast, under sowing scheme B, both R6 and CR6 significantly increased emergence rate compared with CK and CR6 showed the stronger promotive effect in field direct sowing. Emergence rates rose by 5.00 and 12.29 percentage points relative to CK for R6 and CR6, respectively (Figure 4B). For mean emergence time, there were no significant differences among R6, CR6 and CK in scheme A. In scheme B, R6 did not differ from CK, whereas CR6 significantly accelerated emergence, shortening the mean time by 2.26 days (Figure 4C).

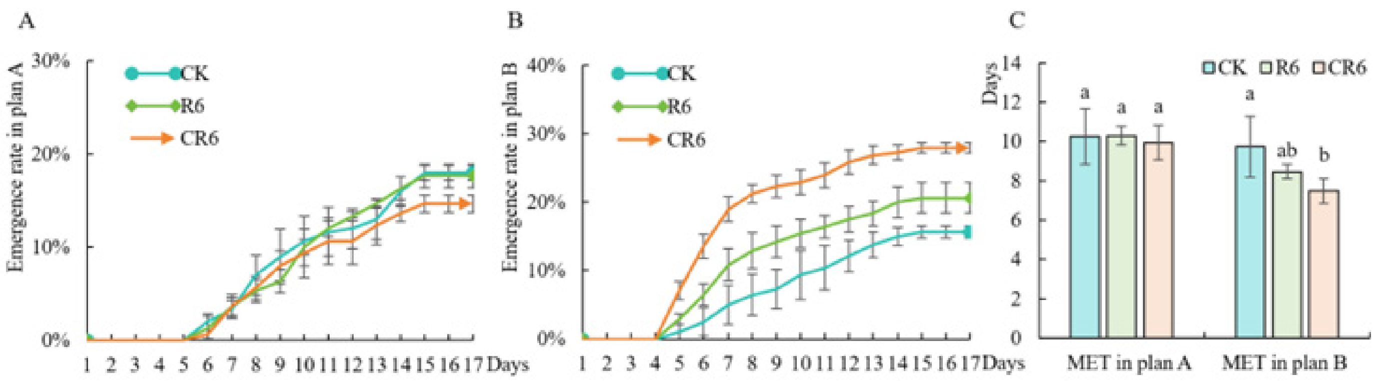

Figure 4: Effects of Cc in direct seeding field trials with scheme A and B.
A) The emergence rate of Cc seeds with scheme A; B) The emergence rate of Cc seeds with scheme B; C) The MET of Cc seeds with scheme A and B. Results are presented as mean ±SD, one-way ANOVA and Duncan test were used; n=3; different lowercase letters indicate significant differences between treatments (P<0.05).

Discussion

Seed coating was originally designed to alter the external physical properties of seeds to improve seed handling and enable precision sowing, pelleting process would remain neutral in its influence on the germination and seedling performance [19]. However, as pelleting technology has evolved, the addition of additives into the pellet filler has repeatedly resulted in seed quality and plant performance that surpass those of the naked seed. Cockscomb seeds are extremely small (0.8-1.2mm in diameter). In this study, the pelleting formulations R6 and CR6 significantly increased seed volume and weight, achieving a 94% seed retention rate and offering the prospect of precision sowing for both plug tray and field production of cockscomb. Across laboratory testing, plug tray sowing and field direct sowing, the R6 formulation improved emergence rate, mean germination time, mean emergence time, seedling length, seedling dry weight and shoot length to varying degrees, without any evident negative effects or impairment of the seed's original agronomic traits. CR6 provided even stronger promotion than R6, additionally enhancing germination rate, main stem diameter, leaf chlorophyll content and crown diameter. These results are consistent with findings for herbaceous species such as purslane, marigold and broccoli, in which pelleting increased germination rate, germination index, and root and shoot growth [20-22]. This indicates that nutrients contained within the pellet surrounding the root stimulate early seedling growth [23]. Rapid seedling growth and development increase the opportunities for rapid nutrient acquisition and synthesis, thereby positively altering related growth indices.

Nevertheless, in the plug tray sowing testing, the CR6 formulation prolonged the period from sowing to flowering from 75 to 83 days compared with CK. This delay may be due to stronger vegetative growth pushing back the start of reproductive development. Xie et al. [24] reported that pelleted cotton seeds showed the opposite trend, exhibiting an earlier reproductive phase with earlier flowering and boll-opening. Thus, adjusting the nutrient composition of the pellet or incorporating plant growth regulators may offer a means to balance vegetative and reproductive growth in cockscomb. Biochar is rich in carbon and a range of plant nutrients-nitrogen, phosphorus, potassium, calcium, magnesium and other elements essential for plant growth [10]. Its high porosity and large specific surface area enable pelleting filler containing biochar to absorb more water from the environment and promote both seed germination and plant growth [12,13,25]. As demonstrated by Amoroso et al. [26], pelleting seeds of sand rocket, lettuce, tomato, maize with a biochar-containing filler enhanced germination and root elongation in these four crops. In this study, the R6 formulation exerted multiple positive effects on cockscomb seeds and the incorporation of biochar amplified these benefits, making the promoting effects more pronounced. This indicates that biochar can effectively improve the pelleting formulation and positively influences seed germination, seedling emergence and subsequent plant growth. We therefore infer that, even in the laboratory testing where no soil or other nursery substrates were involved, biochar supplied nutrients directly to the emerging radicles, enhanced seedling growth and root development, and consequently increased shoot length and seedling dry weight, which is of great importance for high-yield seed production.

Furthermore, herbaceous ornamental production is often confronted with continuous-cropping obstacles such as pests and diseases and soil nutrient imbalances [27]. It has been demonstrated by multiple studies that biochar has remarkable efficacy in ameliorating soil physicochemical properties [28-30]. Biochar shows great potential as an ideal material for seed coating applications, however, in practice, the proportion of biochar in pelleting formulations must remain within a reasonable range. Excessive levels markedly reduce the seed's compressive strength and can adversely affect germination and subsequent growth performance [31,32]. A study reported by Zhang et al. [32] showed that when biochar accounts for 20-40% of the pelleting filler, it significantly increased seed germination rate, plant height and seedling dry weight, with a content of 30% giving the best seedling performance. Researchers from the University of Florence incorporated biochar at different concentrations into peat-based substrates to evaluate its effects on germination and growth in rocket salad [33]. They found that a moderate biochar content (20% v/v) increased leaf area and fresh biomass, however, higher concentrations (≥40% v/v) altered pH, porosity and electrical conductivity in substrate, causing a sharp drop in germination to only 29% and severely impairing plant development. Elevated biochar rates also exerted negative effects on plant growth. Moreover, in practical applications, Seyedeh et al. [34] demonstrated that combined application of biochar and nitrogen fertilizer outperforms nitrogen applied alone in terms of nitrogen-use efficiency and total nitrogen uptake.

Conclusion and Recommendation

In summary, for cockscomb seed pelleting, the R6 and CR6 formulations proved highly effective, significantly enhancing multiple growth parameters and showing strong potential for large-scale, rapid deployment in ornamental seed-pelleting technology. Under field direct sowing conditions, incorporating colorants into the pelleting formulation can alter seed color and thereby reduce seed loss to birds [35], safeguarding landscape quality in flower-sea displays. Moreover, pelleted seeds do not directly contact the soil, the incidence of soil-borne diseases is markedly lowered, further inclusion of pesticides or biological control agents in the pelleting filler can improve resistance to pests and diseases during germination and seedling development [36,37]. Seed pelleting technology improves germination rate, enhances seedling emergence uniformity and growth consistency, eliminates the need for reseeding, and enables precise sowing-date control. Specialized pelleting technologies can further regulate sowing dates [9]: For seeds sown in arid environments, the incorporation of a water retaining agent into the pelleting filler captures soil moisture and supplies it to the seed, ensuring germination even under drought stress. This expands the feasibility of sowing in extreme habitats such as ecological-restoration sites, breaking the traditional constraints of sowing environment and dating on successful plant establishment. In addition, future research should continue to refine the optimal biochar content to develop even better pelleting formulations for ornamental seeds, ultimately delivering higher-quality products to the market.

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