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Role of Seed Pelleting for Improving Seed Quality and Crop Productivity

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***Abstract*—** *Agricultural crop yield and field performance are strongly influenced by seed quality. Crop establishment is sometimes hampered by unfavourable environmental factors such as high temperatures, moisture stress, soil salinity, and nutritional deficiencies. By applying fillers, binders, nutrients, growth regulators, insecticides, biofertilizers, and beneficial microorganisms to seeds, seed pelleting improves germination and the early growth of seedlings. Research findings indicate significant improvements in germination percentage, seedling vigour, nutrient uptake, stress tolerance, nodulation, disease resistance, and yield quality in crops such as rice, soybean, mung bean, cowpea, sorghum, cotton, onion, black gram, and French bean. Pelleting beneficial microbes, seaweed extracts, micronutrients, and biofertilizers enhances crop sustainability and performance. Despite challenges with time and cost, especially in unusual seed combinations, seed pelleting remains a promising and economically viable approach for improving seed performance and raising agricultural production. In current agriculture, this review study emphasises the uses, advantages, and significance of seed pelleting for sustainable crop production systems.*

***Keywords*— Seed quality, Seed pelleting, Crop yield, Agricultural sustainability.**

I. INTRODUCTION

Many studies have demonstrated that variables including temperature, humidity, drought, soil salinity, soil acidity, and others have a major impact on seed germination, vigour, viability, and eventually seed yield (Patra, 2022; Zaman and Hedayetullah, 2025b). Numerous field crops have been impacted by different seed hardening treatments in terms of yield metrics, crop growth, and germination (Patra, 2025b; Hedayetullah et al., 2025). Post-harvest treatments that boost germination and seedling growth or make it easier for seeds and other inputs/materials needed at the time of sowing to be delivered smoothly are known as "seed enhancement" (Zaman and Hedayetullah, 2026). The main goal of seed enhancement technology is to further improve seed performance by treating seeds with particular chemicals, additives, organics (Hedayetullah et al., 2026), botanicals, etc. under very specific regimes and with the help of specific planting equipment to grow uniform crops, to harness higher productivity and production (Zaman and Hedayetullah, 2025; Patra et al., 2026; Halmer, 2006). This covers three broad areas of improvement: seed conditioning, coating, pelleting technology, and pre-sowing hydration treatment (Patra et al., 2026). Several studies have shown that applying dry physiological treatments (using chemicals, medicinal formulations, and crude plant components) both before and during storage (on freshly harvested items) can greatly reduce seed deterioration and enhance crop field performance (Mandal et al., 2011a, 2011b; Patra, 2017a, 2017b, 2018, 2025a, 2025e; Patra and Burman, 2017; Patra, 2025c; Patra et al., 2012, 2013, 2026a; Hedayetullah et al., 2026; Garai and Patra, 2024).

According to Pedrini et al. (2017) and Afzal et al. (2020), seed pelleting technology is a type of seed coating that combines fillers with seeds through mechanical processing, resulting in seeds with a uniform shape (typically spherical), plump grains, and smooth surface. The increased weight and volume of pelleted seeds effectively solves the clogging problem in mechanical sowing and facilitates precise sowing and large-scale seedling production to reduce production costs (Hedayetullah et al., 2026). Additionally, pelleted seeds can absorb more water and oxygen, which increases the pace of germination (Kangsopa et al., 2018). Insecticides, fungicides, micronutrients, growth regulators, trace elements, dyes, and other materials can also be added to the pellet filler to improve seed quality, germination, and development; make seeds suitable for long-distance transportation and mechanical sowing (Zaman and Hedayetullah, 2025); encourage the growth of seedlings; prevent pests and diseases; improve seed stress tolerance; and improve soil conditions (Hussain et al., 2024; Kangsopa et al., 2018; Oladosu et al., 2022; Zaman and Hedayetullah, 2019, 2021, 2025). Seed pelleting provides an establishing medium and aids in the provision of extra nutrients (Van Wyk, 1983).

One of the most important inputs needed for agricultural development is seed. The adage "Life cycle of a plant begins with seed and ends with seed" illustrates the significance of seed (Zaman and Hedayetullah, 2025). Adopting technologies that could improve seed performance and yield is therefore crucial. It is commonly believed that soil and seed have the greatest influence on crop productivity, with other factors coming in second. Aeroponics and hydroponics are two examples of how soil can be altered and even substituted with water and air in the current environment; however, both methods are uncommon when it comes to seeds. Some physical changes to seeds, like the pelleting process, have been shown to be a scientifically significant method of increasing the production potential of numerous crops, particularly pulses.

Directly altering the size and shape of seeds to create a more uniform mixture is one way to increase sowing efficiency. This is frequently accomplished by seed processing by eliminating (Barberis et al., 2023) or minimising (Berto et al., 2020; Guzzomi et al., 2016) appendages (such as awns and hairs in grass florets) that may affect seed flow (such as bridging). The seed is then coated with tiny powders (fillers) and binders to change its size, density, and form (Brown et al., 2021; Pedrini et al., 2017). Seed pelleting, the type of seed coating that most significantly alters the size and form of the seed unit, can be useful in increasing the effectiveness of seed distribution, particularly for species with small seeds (Hoose et al., 2019; Gornish et al., 2019).

Similar to sowing equipment, this technique was created to pellet one species at a time and came from the crop and horticultural seed sector (Afzal et al., 2020). The majority of research has used seed pelleting on individual native species for ecological restoration (Beveridge et al., 2020; Hoose et al., 2019; Madsen et al., 2014; Pearson et al., 2019; Pedrini et al., 2023; Turner et al., 2006; Westbrook et al., 2023). This enables the modification of pelleting recipes according to species, taking into consideration elements such as germination requirements, which could enhance establishment results. However, when used with different seed mixes, this method has certain practical disadvantages. According to a recent study by Pedrini et al. (2023), pelleting the seeds of 15 small-seeded Myrtaceae species takes an average of 98 minutes, ranging from 37 to 188 minutes per species (Singh et al., 2014). This implies that the more diverse a mix is, the longer and more costly the pelleting process will be, rendering the technique economically unfeasible and negating any possible gains in seeding efficiency from using pelleted seeds (Roy et al., 2025).

II. TYPES OF SEED PELLETING

a) **Traditional Pelleting:** By adding an inert covering, this technique enhances the size and shape of the seed without altering its characteristics.

b) **Nutritive Pelleting:** Contains fertilizers or micronutrients to encourage early growth.

c) **Chemical Pelleting:** Uses pesticides, fungicides, or insecticides to protect seeds from diseases and pests.

d) **Biological Pelleting:** Uses beneficial microbes to promote plant growth and health.

e) **Innovative Polymer Pelleting:** Under controlled circumstances, this method delivers nutrients or protective materials using biodegradable polymers.

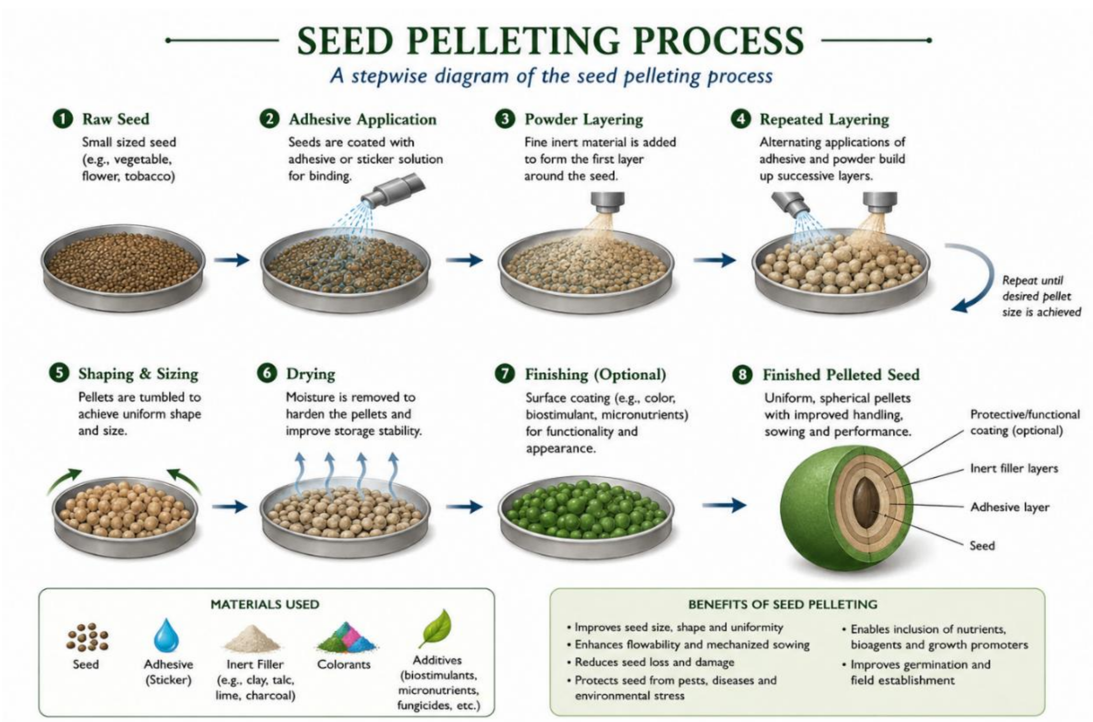

FIGURE 1: Schematic diagram of the seed pelleting process showing steps from raw seed to pelleted seed

Note: The seed pelleting process typically involves: (1) Seed cleaning and sorting, (2) Application of adhesive/binder (e.g., gum arabica, maida gum), (3) Addition of filler material (clay, diatomaceous earth, etc.), (4) Addition of active ingredients (micronutrients, biofertilizers, pesticides), (5) Drying, (6) Sieving and quality control, (7) Packaging and storage.

III. SEED PELLETING APPLICATIONS FOR SEED PERFORMANCE IN SEVERAL AGRICULTURAL CROPS

Mechanical integrity is a crucial characteristic of pelleted seeds. According to Hill (1999), a pellet must have enough structural integrity to withstand drying, packing, transportation, storage, and deployment without shattering or collapsing (Singh et al., 2014). According to Nuyttens et al. (2013), mechanical integrity and the capacity to hold active ingredients onto the seed are crucial, particularly when pellets are laden with substances like pesticides that could be hazardous to both the environment and human operators.

To increase abiotic stress tolerance during seed germination, a number of techniques have been used. In many field crops, especially in unfavourable environmental conditions, seed pelleting is an efficient, useful, and simple method to improve speedy and uniform emergence, high seedling vigour, and superior yields (Powell and Matthews, 1988). According to Rocha et al. (2019), applying silicon dioxide and starch to cowpea and grass pea seeds coated with *Pseudomonas putida* greatly enhanced biomass and seed yield under water deficiency. Rice seeds pelleted with clay or diatomaceous clay showed germination percentage improvements of 26% and 43%, respectively, as compared to naked seeds (Rahaman et al., 2022; Sadhukhan et al., 2018). According to some studies, pelleted tobacco seeds made with a superabsorbent polymer, polyhydrogel, and salicylic acid (SA) greatly improved seed germination, seedling growth, and drought tolerance (Guan et al., 2014).

A field experiment on soybeans grown in red sandy clay loam soil was carried out by Ramesh and Thirumurugan (2001). According to the findings, soybean seed pelleting with ammonium molybdate at 250 mg/kg and ferrous sulphate at 500 mg/kg of seeds (inoculated with *Rhizobium*) increased soybean yield and growth metrics. Nodulation and grain yield were enhanced in mung bean seed pelleted with lime, gypsum, calcium carbonate, calcium sulphate, and rock phosphate (Pedrini et al., 2017). Ramamoorthy and Sujatha (2007) investigated the effects of pelleting herbal seeds with *Vitex* and *Calotropis* leaf powder (Acacia and maida gum were used as adhesives). The experimental findings showed that pelleting seeds with *Calotropis* or *Vitex* at 100 g/kg of seed + 15% maida gum + 30% Acacia gum followed by drying was beneficial in improving the physiological and yield parameters in greengram.

According to the experimental results, compared to $MnSO_4$ hardening and control, seeds that were hardened and pelleted with *Prosopis* leaf extract showed greater values of field emergence percentage, survival percentage, chlorophyll content, seed number per pod, pod yield, and seed yield. Grain yield, seed weight, and seed yield increased by 32.1% when cowpea seed pelleting with $ZnSO_4$ at 200 mg/kg of seed was applied (Masuthi et al., 2009; Hedayetullah and Zaman, 2018a, 2018b). In a similar vein, they found that, in comparison to non-pelleted seed, cowpea seed pelleting with borax considerably enhanced the number of pods, grain weight, and grain production. Because there were fewer galls and egg masses per root system in both crops for up to 360 days, pelleted seeds kept at 4°C demonstrated a decrease in root-knot nematode infection. Additionally, the authors found that using powdered leaves and stems as pelleting material outperformed pneumatophore powder.

Kumar et al. (2014) reported the positive effects of polymer seed coating, while Raju and Rai (2017) validated the positive effects of seed coating with polymers on pigeon pea in another laboratory trial. Biofertilizers have been shown to improve growth, dry matter output, root weight, and collar diameter in a variety of tree species (Saravanan, 1991). When seeds are pelleted with phosphate fertiliser, crop plants have been shown to produce more biomass (Bapat and Umale, 1973). When sorghum seeds are pelleted with micronutrients and diammonium phosphate (DAP), their germination, root length, shoot length, and vigour index all reach their maximum. According to Saraswathi (1994), cotton seeds pelleted with gypsum and DAP also exhibit the aforementioned criteria.

Overall, the results show that seed pelleting improves germination, crop growth, flowering, yield characteristics, and overall field performance in a selection of crops, including onion, French bean, and black gram. In order to improve seed performance and crop yield, seed pelleting involves covering seeds with advantageous materials such as micronutrients, biofertilizers, biocontrol agents, and compounds that promote plant growth. Pelleted black gram seeds showed greater germination rates than untreated seeds, as illustrated in Fig. 2. Seaweed extracts, micronutrients ($ZnSO_4$, $MgSO_4$, sodium molybdate), and beneficial microbes (*Trichoderma viride*, *Rhizobium*, and phosphobacteria) improved seed metabolism, water absorption, and early seedling growth. Plants grown from pelleted seeds were taller and more vigorous. Improved nutrient availability and microbial activity encouraged root development and nutrient absorption in both French beans and black gram, leading to better plant growth and establishment. Black gram's first flowering phase was shortened by seed pelleting (Fig. 2), indicating faster crop development. Early flowering may aid in timely harvesting and assist crops in avoiding late-season stressors. Seed pelleting greatly increased the number of seeds per pod in black gram (Fig. 2) and yield-related measures in French beans (Fig. 3). Higher output resulted from the early growth stages' constant supply of beneficial bacteria and micronutrients, which improved reproductive development.

Pelleting with zinc sulphate, boric acid, and microbial consortia enhanced field emergence, plant development, and overall crop performance, as seen in the onion study (Fig. 4). Precision sowing and improved plant stand establishment were made possible by uniform pellet size, which is crucial for small-seeded crops like onions. According to Singh et al. (2022), the study showed that seed pelleting had a favourable impact on cowpea seed performance and seedling establishment, indicating its potential as a practical seed improvement approach for increasing crop stand and productivity (Fig. 5).

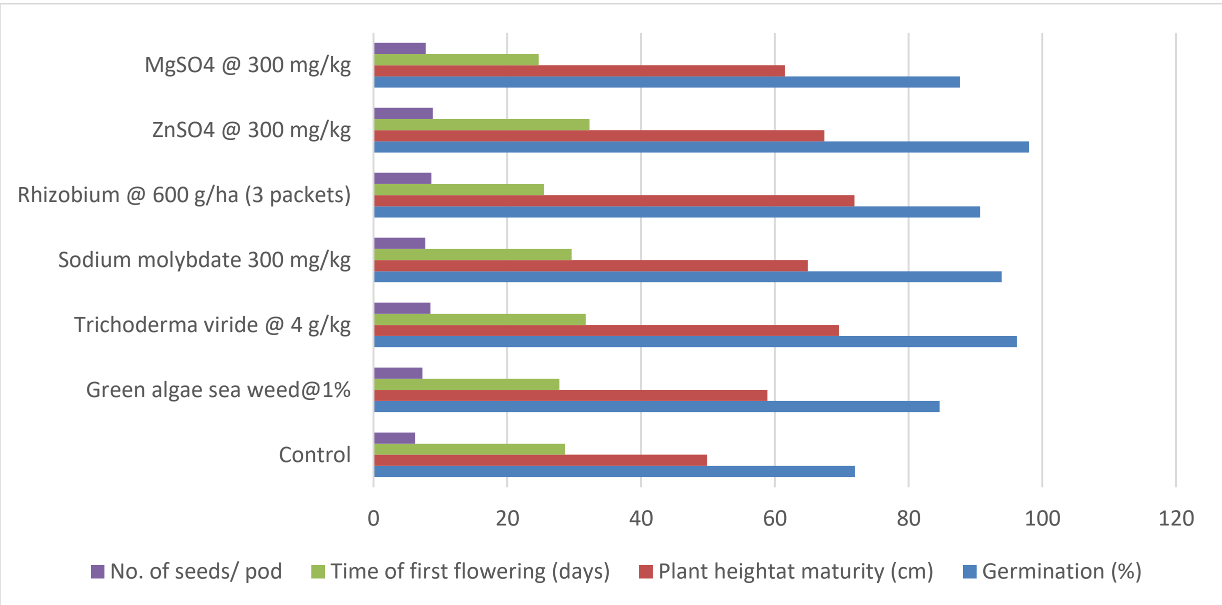

FIGURE 2: Impact of seed pelleting on black gram germination percentage, plant height, first flowering period, and number of seeds per pod

Source: Dubey et al. (2023)

Note: *After cleaning the seeds by hand, the required amount was placed in a container together with 400 millilitres of gum arabica adhesive per kilogram of seed. The container was then completely combined by shaking and turning. The pelleting materials were treated with red algae seaweed extract at 1%, brown algae seaweed extract at 1%, green algae seaweed extract at 1%, Trichoderma viride at 4 g/kg, Rhizobium at 600 g/ha (3 packets), Phospho-bacteria at 600 g/ha (3 packets), Sodium molybdate at 300 mg/kg,* $ZnSO_4$ *at 300 mg/kg, and* $MgSO_4$ *at 300 mg/kg. The seeds were continuously shaken and rotated to ensure that the micronutrients were uniformly coated. The pelleted seeds were employed for both field sowing and laboratory research after being dried for a full day.*

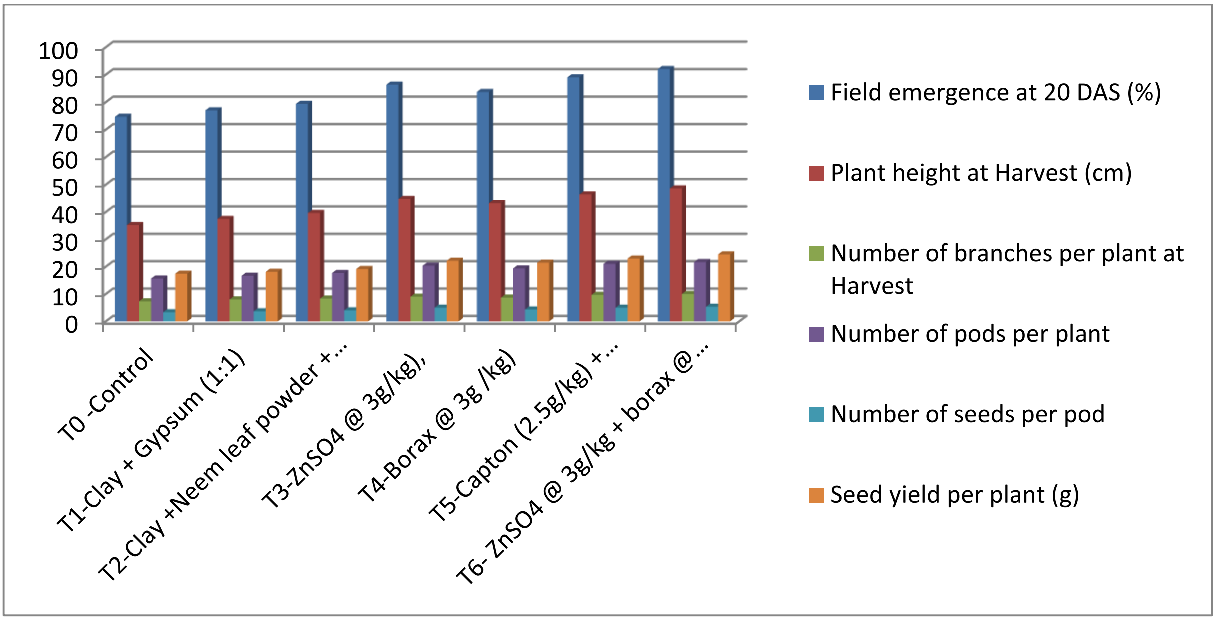

FIGURE 3: Influence of seed pelleting on crop performance in French bean cv. Arka Anoop (*Phaseolus vulgaris*)

Source: Chaya Devi et al. (2017)

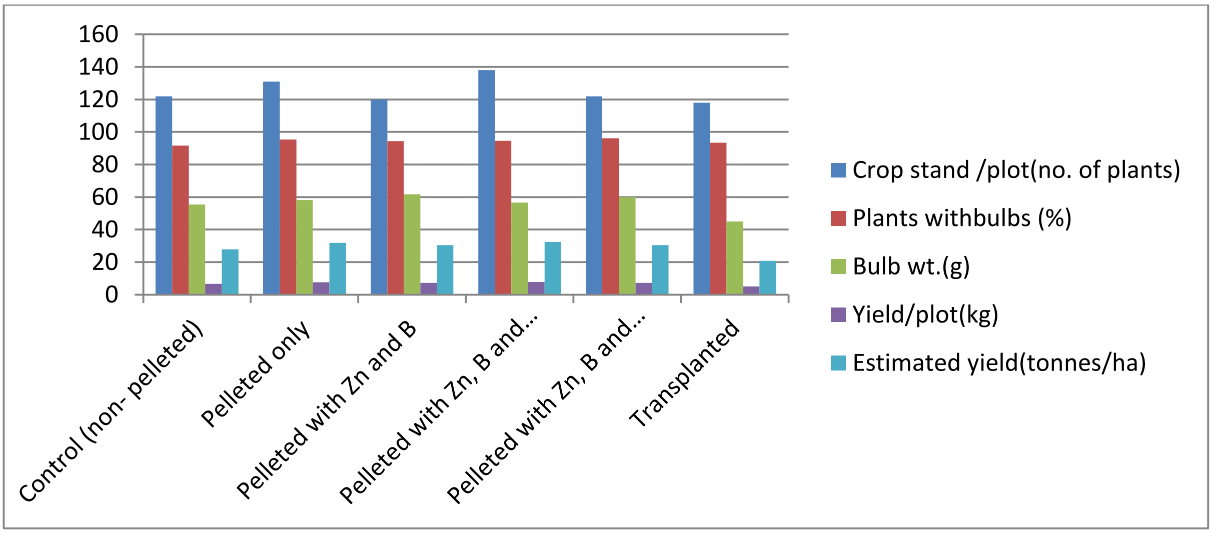

FIGURE 4: Field performance of pelleted onion seeds

Source: Yogeesha et al. (2017)

Note: *Pellets were taken out of the pan and dried in shade for one day and then under sunlight till the moisture content of the pellets reduced to < 8 percent. Dried pellets were sieved first using 2.5 mm round sieve to remove pellets without seed and few undersized pellets and then sieved using 3.5 mm round sieve to remove few pellets with double seeds. Further, micronutrients such as zinc sulphate 5% and boric acid 1% and microbial consortium, viz. Actinomycetes + Bacillus aryabhattai (Microbial consortium I) and Bacillus subtilis + Trichoderma harzianum (Microbial consortium II) were incorporated concurrently along with pelleting material in the following combinations: 1) Pelleted only; 2) Pelleted with Zn and B; 3) Pelleted with Zn, B and* *microbial consortium I; 4) Pelleted with Zn, B and microbial consortium II; 5) Control (non-pelleted). The seeds were soaked in enough quantity of broth containing Actinomycetes + Bacillus aryabhattai at 10^6 cfu/mL for 5 minutes before pelleting. In the case of Bacillus subtilis + Trichoderma harzianum, the seeds were coated with a slurry containing consortium mixed with vermicompost powder and then surface dried before pelleting as described by Mohan Kumar et al. (2015). Micronutrients, viz. zinc sulphate and boric acid were ground into fine powder and mixed with the pelleting mixture.*

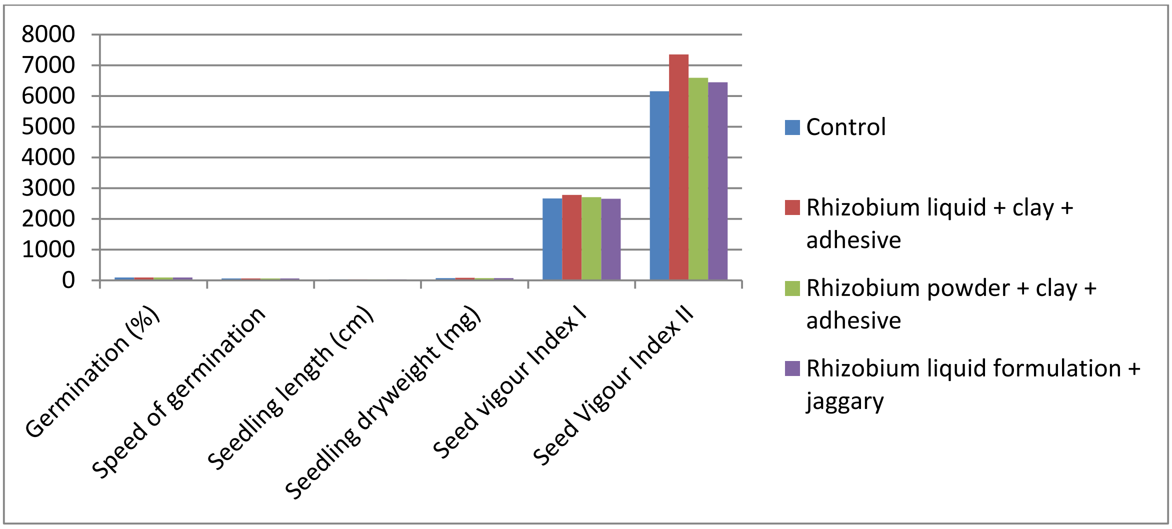

FIGURE 5: Effect of seed pelleting on seed quality parameters of cowpea

Source: Singh et al. (2022)

Note: Seed pelleting with clay and adhesive (45% Gum Arabica) was used.

IV. CONCLUSION

Pelleting seeds is a useful technique for improving seed germination, seedling establishment, plant growth, flowering, yield characteristics, and field performance. A useful and affordable method of boosting crop productivity and achieving sustainable agricultural output is the incorporation of micronutrients, biofertilizers, biocontrol agents, and seaweed extracts into pelleting formulations. The main obstacle to pulse production—low productivity—can be greatly addressed by seed pelleting. Since pulses are the best vegetarian source of protein, increasing their output is also essential if we want to feed our population properly. In order to increase the rate at which farmers adopt seed pelleting, it is currently necessary to identify crop-specific seed pelleting procedures for various crops and to educate farmers about its advantages.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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