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SEED PELLETING MEDIATED IMPROVEMENT IN GROWTH, YIELD AND SEED STORABILITY OF ONION (*ALLIUM CEPA* L.)

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ABSTRACT

Poor seed storability and weak field establishment remain major constraints in onion production particularly under direct seeding systems. The present investigation examined the influence of seed pelleting with nutrient and bioactive based formulations on crop establishment, growth, yield attributes and seed storability in onion. Field and laboratory experiments were conducted using pelleted and non-pelleted seeds of Gujarat Junagadh Red Onion 11. Seed pelleting significantly enhanced initial and final plant stand, promoted vegetative growth, accelerated maturity, improved bulb size and yield parameters. In addition, pelleted seeds maintained higher germination percentage, seedling vigour index, and seedling dry matter accumulation during storage indicating delayed physiological deterioration. The positive response observed is attributed to improved nutrient availability and favourable micro environment around the seed during germination and early growth. The study demonstrates that seed pelleting serves as a practical and biologically effective strategy for improving onion productivity and seed quality with implications for enhancing seed performance under direct seeding systems.

Keywords : Seed pelleting, Onion, Humic acid, Micronutrients, Seed storability

Introduction

Onion (*Allium cepa* L.) belongs to the genus *Allium* under the family Alliaceae having chromosome number $2n = (2x) = 16$ and is said to be native to Central Asia and the Mediterranean region. According to a recent classification based on cladistic, genomics and molecular polygenetic relationships, onion is a monophyletic monocot under clad Liliales (Sharma *et al.*, 2006). Onion is the most important bulb crop cultivated commercially all over the world and it's the second most important horticultural crop after tomato in the world. It's consumed as raw or a component of meals in many different cultures around the world. Also, unlike many other vegetable species, consumption of onion is not limited to a particular season. Onion is available almost throughout the year in most parts of the country due to optimum growing conditions. Indian onions are famous for their pungency due to the presence of a volatile oil 'Allyl propyl disulphide' ($C_6H_{12}S_2$) (Afzal *et al.*, 2020) and are available around the year. Onion is also known as

"Queen of the Kitchen". It is valued for its characteristics flavour, pungent taste and medicinal importance. Anti-fungal activities in onion are due to a phenolic factor *i.e.*, Catechol (Padmini *et. al.*, 2007). It is valued for its characteristics flavour, pungent taste and medicinal importance. Anti-fungal activities in onion are due to a phenolic factor *i.e.*, Catechol (Chakraborty *et al.*, 2022). Nutritionally, onions are low in calories (about 40 calories for an average-sized onion) and high in ascorbic acid (Corzo-Martínez *et al.*, 2007).

Seed is the reproductive unit responsible for ensuring successful establishment for most agricultural especially vegetable crops. The use of quality seed is the most important factor as quality seeds ensure better germination as well as better yield. Quality seed comprises those properties, which determine the potential for rapid uniform emergence and development of normal seedlings under a wide range of field conditions. Seed deterioration can be defined as the loss of quality, viability and vigour either due to

ageing or the effect of adverse environmental factors. Several environmental factors contribute to seed deterioration and these conditions make it very difficult to maintain seed viability during storage (Kamaei *et al.*, 2024). Reports indicate that onion seeds exhibit very short life and lose their viability within 1-2 years (Khan *et al.*, 2004; Yalamalle *et al.*, 2020). Onion seeds usually have a low quality, resulting in slow and asynchronous germination as well as seeds producing a high number of abnormal seedlings (Borowski *et al.*, 2006). One of the major constraints in onion cultivation is the limited availability of vigorous seeds at the time of sowing due to the poor storability of these crop seeds under fluctuating ambient temperatures and relative humidity. Many investigators reported that the speed of decline in seed quality is largely dependent on storage temperature, relative humidity, seed moisture content, length of storage, type of seed and seed quality (Alhamdan *et al.*, 2011). Studies show that drying onion seeds to around 5-6% moisture and keeping them cold (4–15 °C) can preserve viability for over a year. Conversely, warm, humid storage leads to rapid quality loss (Dorna *et al.*, 2023). Packaging and controlled atmosphere storage also make a difference (Thomas *et al.*, 2024; Lamani *et al.*, 2020).

Seed pelleting is a mechanism of applying various materials to the seed that can enhance the seed quality concerning physiological, physical and health attributes. Often, these substances are fungicides, insecticides, micronutrients and other compounds. Seed pelleting also makes it easy to handle small and irregularly shaped seeds and facilitates accurate dosing of seed with chemicals and wastage is prevented. The seed coated with certain substances enhances yield, improved quality and emergence, coating of seed with adhesive in combination with the active ingredient, has been reported to be effective (Vanangamudi *et al.*, 2010). However, recommendations on the sowing time of direct seeded onion are lacking. The direct seeding of pelleted onion seeds needs to be precisely studied to avoid production problems like early bolting and delayed harvesting that coincide with monsoon rains resulting in loss of yield and quality (Panwar *et al.*, 2019).

Onion seeds are among the shortest-lived vegetable seeds and exhibit wide variation in germination among seed lots. Maintaining seed viability is essential to preserve genetic integrity and ensure seed availability between seasons. Being hygroscopic in nature, the viability and vigour of seeds under storage are known to be regulated by variations in the physio-chemical factors, initial seed quality,

storage structure, packaging materials etc (Doijode *et al.*, 1990). Seed treatment with chemicals is found to be more useful in storage for maintaining better seed quality for one year in onion by suppressing the storage pests and fungi (Gupta *et al.*, 1989). The safe and feasible approach is the treatment of seeds with botanicals, organics, etc. Which are safe, economical, cheap eco-friendly in nature and nontoxic to man and animals. Among botanicals, using castor, neem powder and neem oils are proven to be effective protectants against storage insects; they can reduce infestation and maintain the quality of the seed in terms of viability and vigour for a longer period in storage (Kulkarni *et al.*, 1989).

Material and Method

Experiment details

The experiment was conducted during rabi 2023-24 at the Centre for Forage Research, S.D.A.U., Sardarkrushinagar., while the laboratory experiment was carried out from summer 2023 and onwards at the Seed Testing Laboratory, Department of Seed Science and Technology, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The experimental layout, observations details are given in Table 1, Table 2 respectively. Pelleted and non-pelleted seeds are shown in Figure 1.

Experimental material

Gujarat Junagadh Red Onion Variety 11 (GJRO 11) variety was used to experiment and was been received from the Main Vegetable Research Station, Junagadh. Pelleting of the onion seeds was done by INCOTEC India Pvt. Ltd., Ahmedabad.

Method of Sowing

The onion seeds were sown by direct sowing. Seeds were sown by dibbling at the congenial field conditions. The seeds were hand-dibbled at two to three cm deep in the earlier marked row at a spacing of 15 cm. The plant distance was kept at 10 cm.

Statistical analysis

The experimental data of field trials and laboratory trials were analysed statistically by adopting Randomized Block Design (Factorial) and Completely Randomized Design (Factorial), respectively, as described by Cochran and Cox (1957) (Cochran & Cox 1957). The critical differences were calculated at a 5 per cent level, where the 'F' test was found significant.

Result

Effect of pelleted seeds on different sowing methods

Crop Establishment

Seedling emergence is the foremost component of crop success. From the results, it was seen that irrespective of treatments, different methods of sowing manifested significant effects on the initial and final plant population (Figure 2 and Supplementary Table 1). The seeds treated with micronutrient grade-4 (T5) had significantly the highest initial and final plant population. In the interaction effect, direct sowing of seeds (S1T5) seeds pelleted with micronutrient grade-4 (T5) produced the relatively highest initial and final plant population, and it was statistically at par with seeds pelleted with humic acid (S1T4) and plant growth hormones (S1T6). By contrast, plain (control) or hormone treated seeds had lower stand. These findings suggest that incorporating nutrients or bio stimulants into the pellet can boost seedlings establishment.

Phenology

Pelleted seeds consistently matured earlier than non-pelleted seed. Thus, seed pelleting accelerated crop phenology by 10-12 days. Seeds pelleted with humic acid (T4) (S1T4) and micronutrient grade 4 (T5) (S1T5) had the significantly lowest days to maturity 123.33 and 128.67, respectively. Non-pelleted seeds treated by the N.P.K (T3) showed significantly the highest number of days to maturity (154.00) (Figure 2 and Supplementary Table 2)

Vegetative Growth

Pelleting had a pronounced positive effect on vegetative growth. When compared to non-pelleted seed (S2), pelleted (S1) onion seeds showed a significantly higher number of leaf per plant, average leaf length and plant height throughout the sowing methods. The underlying cause is that pelleted seeds with embedded nutrients germinate more vigorously and establish more robust seedlings. The interaction effect of sowing methods and seed treatments was significant. The highest number of leaves per plant and plant height were recorded in direct seeding of seed pelleted with humic acid. Direct seeding of seeds treated with Micronutrient grade 4 had the highest average leaf length (46.13 cm), which was statically at par with the average leaf lengths of 42.96 cm, 43.82 cm, and 43.66 cm for seeds treated with T2, T3, and T4. Seeds pelleting with bio stimulant additives creates more vigorous vegetative growth (Figure 3 and Supplementary Table 3).

Bulb Development and Size

Pelleted onion seeds produced significantly larger bulbs with respect to polar and equatorial dimensions. There is increase of 12.8% in polar diameter with mean polar diameter 42.45 mm with pelleted seed and 37.62 mm with non-pelleted seed. Equatorial diameter showed 20.5% increase. The largest bulb diameter was achieved by combining pelleting with nutrient treatment. S1T4 gave polar diameter of 46.95 mm and equatorial of 58.92 mm, while S1T5 gave 62.32 mm equatorial diameter. These diameters translate to much higher bulb index with mean BSI 2450 mm² in pelleted against 1789 mm² in non-pelleted. Thus, humic and micronutrient pellets produced the highest indices (Figure 4 Supplementary and Table 4).

Yield Components

All yield components were significantly enhanced by seed pelleting and by certain seed treatments. Pelleted plots had roughly three times more bulb per area, reflecting the higher initial stand. Among treatments, humic pelleted seeds produced most bulbs followed by micronutrient pelleted and in contrast with non-pelleted and NPK treated seeds. The highest bulb yield per plot was recorded in S1T5 and S1T4. Finally, the average bulb weight was heaviest in bulbs treated with humic-pelleted seed (S1T4). Plant growth hormone treated seeds (T6) yielded the smallest bulbs, expressing that not all seed treatments are beneficial (Figure 5 Supplementary Table 5).

Effect of seed pelleting on seed storage and seed viability

Seed pelleting exerted a significant influence on seed quality parameters across storage durations as reflected in germination percentage, seedling length, seedling dry weight, seedling vigour index I and seedling vigour index II. Across all storage periods, pelleted seeds consistently recorded significantly higher germination percentage compared to non-pelleted seeds. Germination declined progressively with storage duration. However, pelleted seeds-maintained viability throughout six months of storage. Among treatments, seeds pelleted with humic acid registered the highest germination values at all storage intervals, whereas the lowest germination was observed in seeds treated with plant growth hormone. Seedling length and seedling dry weight were significantly affected by seed pelleting, treatments and storage duration. Pelleted seeds produced longer seedlings and higher dry weight at all stages of storage. Seedling length and dry weight decreased with increased storage duration. The interaction effect was significant at later stages with S1T4 exhibiting the

longest seedling length and highest seedling dry weight after six months of storage. Seedling vigour index-I and seedling vigour index-II showed significant variation due to seed pelleting, treatments, and their interaction across all storage durations. Pelleted seeds exhibited markedly higher SVI-I and SVI-II than non-pelleted seeds, though values declined with storage time. Among treatments, humic acid (T4) recorded the highest SVI-I and SVI-II at all storage intervals, whereas plant growth hormones (T6) resulted in the lowest vigour indices. The interaction effect was significant, with S1T4 producing the maximum SVI-I and SVI-II after six months of storage (Figure 6 and Supplementary Table 6,7,8,9,10).

Discussion

Seed pelleting enhanced onion crop performance by improving early soil seed interactions and establishing a uniform physiological baseline for subsequent growth, yield formation and seed quality (Javed *et al.*, 2022; Afzal *et al.*, 2022; Pedrini *et al.*, 2017). The coordinated response across development and post-harvest traits indicates that pelleting functions as a system level seed enhancement strategy rather than a single trait intervention. Improved crop establishment under pelleted seeds can be attributed to greater seed uniformity, improved seed placement and enhanced soil contact, all of which are critical for onion due to its small size and slow initial growth. Uniform emergence reduces intra specific competition and promotes synchronized crop development. The results are in agreement in onion (Yogeesha *et al.*, 2017) and other crops (Rathod & Jadhao, 2006). Advancement in crop maturity under pelleted treatments suggests enhanced physiological efficiency during early growth stages (Javed & Afzal, 2018). The incorporation of humic acid and micronutrients within the pellet matrix likely stimulated enzymic activity, nutrient uptake, and hormonal regulation facilitating rapid early development and early bulb initiation (Nisar *et al.*, 2025). The result is in agreement in sesame (Kumar *et al.*, 2013), bhindi (Prakash *et al.*, 2014), and rajma (Rajput *et al.*, 2022). Early maturity is agronomically advantageous for rabi onions for avoiding late season stress (Swati, 2017). Enhanced vegetative growth observed under pelleted seeds reflects increased photosynthetic capacity and sustained biomass accumulation. Improved leaf development indicates stronger source strength. Humic based pelleting may have supported root development and nutrient acquisition while micronutrient enrichment supported critical biochemical processes such as chlorophyll synthesis and carbohydrate metabolism. The findings are in agreement in sesame (Kumar *et al.*, 2013), onion

(Swati, 2017), Rajma (Rajput *et al.*, 2022) and sesame (Wasanthika *et al.*, 2022). The positive response of bulb morphology to seed pelleting explains effective conversion of vegetative vigour into sink development. Reduced competition due to uniform spacing, coupled with improved nutrient availability likely enhanced assimilate partitioning towards bulb enlargement. Improved bulb size and uniformity are agronomically and economically significant, as market value in onion is strongly influenced by bulb dimensions and consistency. Yield improvement under pelleted seeds represents the cumulative outcome of better establishment, sustained vegetative growth and enhanced bulb development. Pelleting improves precision sowing, reduces the need of thinning and gap filling and improves population management. The yield advantage of pelleting is consistent with in onion (Yogeesha *et al.*, 2017; Prakash *et al.*, 2014; Swati 2017), sesame (Kumar *et al.*, 2013) and soybean (Rathod *et al.*, 2006). Beyond field performance seed pelleting positively influenced seed physiological quality and storability during ambient storage. Pelleted seeds exhibited delayed deterioration maintaining higher germination potential and seedling vigour over time. The pellet coating buffered seeds against rapid moisture fluctuations and oxidative damage preserving membrane integrity and metabolic stability. Additionally, embedded micronutrients and bioactive compounds slowed seed ageing by limiting lipid peroxidation and sustaining cellular homeostasis. Overall, the integrated improvements in growth, yield and seed quality demonstrate that seed pelleting particularly with humic acid and micronutrient formulations offer a practical and agronomically sound strategy for improving onion productivity and seed longevity (Dubey *et al.*, 2023; Sharma *et al.*, 2024). These findings support that adoption of seed pelleting as an effective method for enhancing crop performance from sowing to storage.

Conclusion

The results clearly establish seed pelleting as a biologically relevant and agronomically efficient seed enhancement technique in onion. Pelleting improved crop establishment, promoted vegetative growth, accelerated maturity, improved bulb size, yield parameters and storability thus addressing the critical constraints in direct seeding in onion cultivation. The consistent superiority of humic acid and micronutrient-based formulations explains their role in enhancing early physiological process and sustaining seed vigour during storage importantly the benefits of pelleting extended beyond field performance to post harvest seed quality reflecting system wide impact. Seed

pelleting can be recommended as a viable intervention for improving onion seed performance and productivity particularly under resource constrained and variable growing conditions.

Table 1: Experimental layout:

Experimental Design	Randomized Block Design with Factorial Concept for field study (FRBD) Completely Randomized Design with Factorial Concept for Laboratory Study (FCRD)	
Replications	3	
Spacing	15 cm x 10 cm	
Plot Size	(a) Gross: 4.0 m × 1.5 m (10 row) (b) Net: 4.0 m × 0.9 m (6 row)	
Germination method	Top of paper method (Petri plate)	
Treatments	Sowing Method	S1 - Pelleted Seed S2 - Non-Pelleted Seed
	Pellet Seed + Treatment	T1 - Raw seed (control)
		T2 - Pelleted Seed (Standard pellet)
		T3 - N.P.K consortia (5 ml/Kg)
		T4 – Humic acid + Atonic Enzyme + Fulvic Acid + K ₂ O + Nitro Benzin (5 gm/Kg)
		T5 - Micronutrient grade 4 [Fe + Zn + Cu + B] (5 gm/Kg)
		T6 -Plant growth hormones [Humic Acid + Amino Acid + Gibberellic Acid + Brassino Sterols + Enzyme] (5 ml/Kg)
	Storage Time (t)	t ₀ – 0 Month
		t ₁ – 2 Month
		t ₂ – 4 Month
t ₃ – 6 Month		

Table 2: Observations taken in the experiment:

Laboratory Experiment	Field Experiment
Germination percentage	Initial plant population
Seedling Length(cm)	Final plant population
Seedling Dry Weight(mm)	Days to Maturity
Seedling Vigour Index I	Number of leaves per plant
Seedling Vigour Index II	Average leaf length
	Plant height at harvesting (cm)
	Polar diameter (mm)
	Equatorial diameter (mm)
	Bulb size index (mm ²)
	Number of bulbs per plot
	Bulb yield per plot (kg/plot)
	Average bulb weight (g)

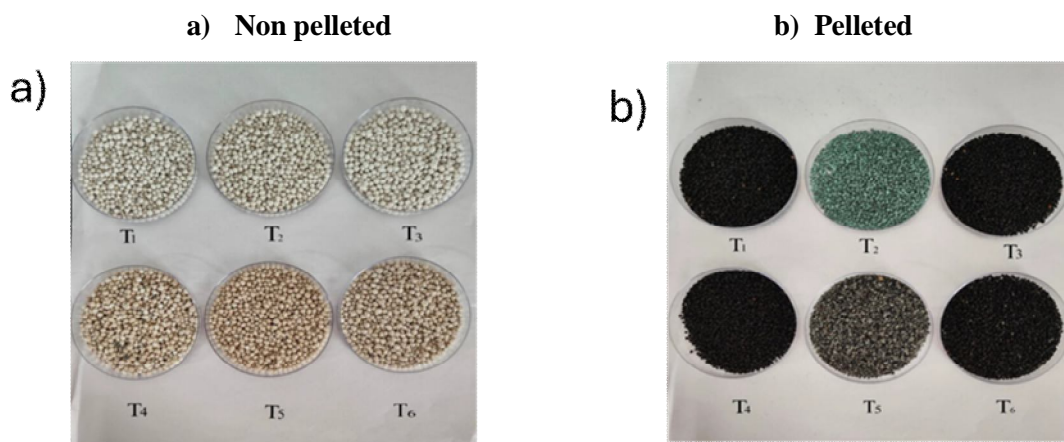


Fig. 1: Pelleted and non-pelleted seeds of onion as per treatment

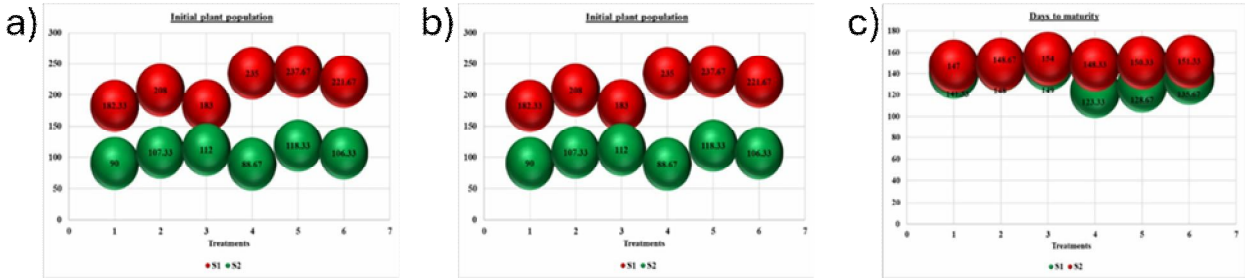


Fig. 2: Effect of sowing method treatments and their interaction effect on Crop Establishment and Phenology
 a) Initial plant population b) final plant population c) Days to maturity

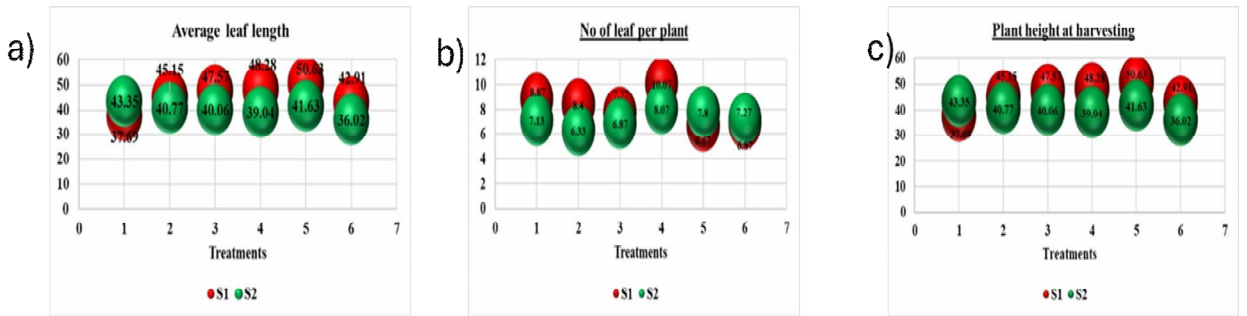


Fig. 3 : Effect of sowing method treatments and their interaction effect on Vegetative Growth
 a) No. of leaf per plant b) Average leaf length c) Plant height at harvesting

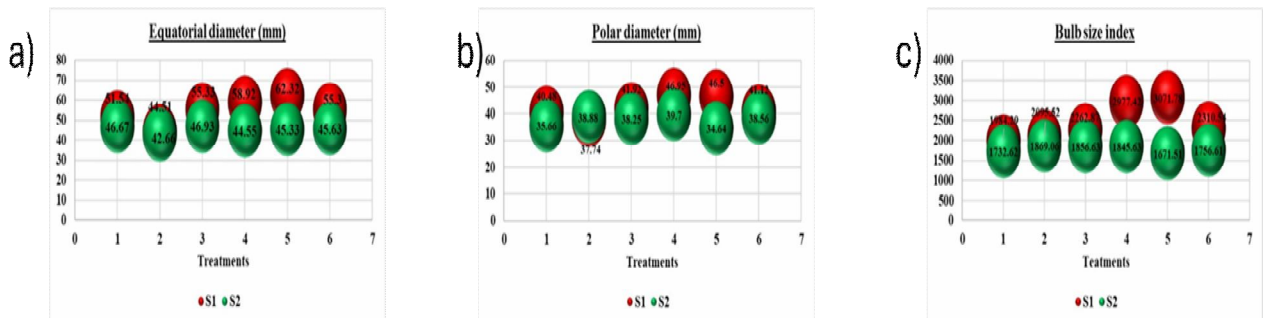


Fig. 4: Effect of sowing method treatments and their interaction effect on Bulb Development and Size
 a) Polar diameter b) Equatorial diameter c) Bulb size index

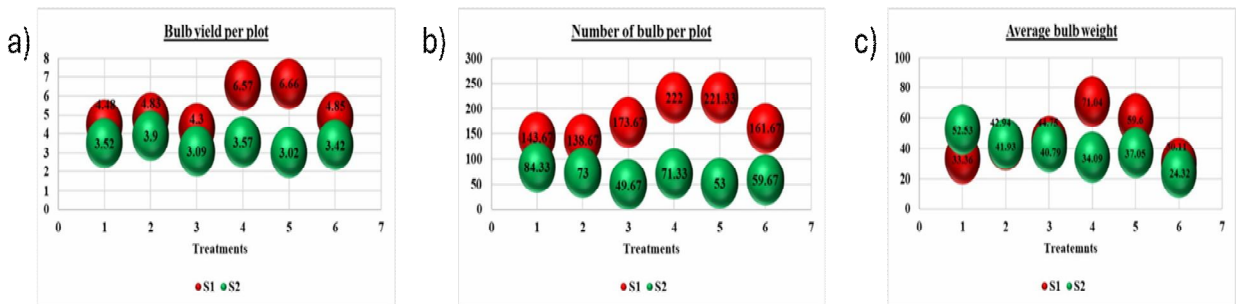


Fig. 5: Effect of sowing method treatments and their interaction effect on Yield Components
 a) Number of bulbs per plot b) Bulb yield per plot c) Average bulb weight

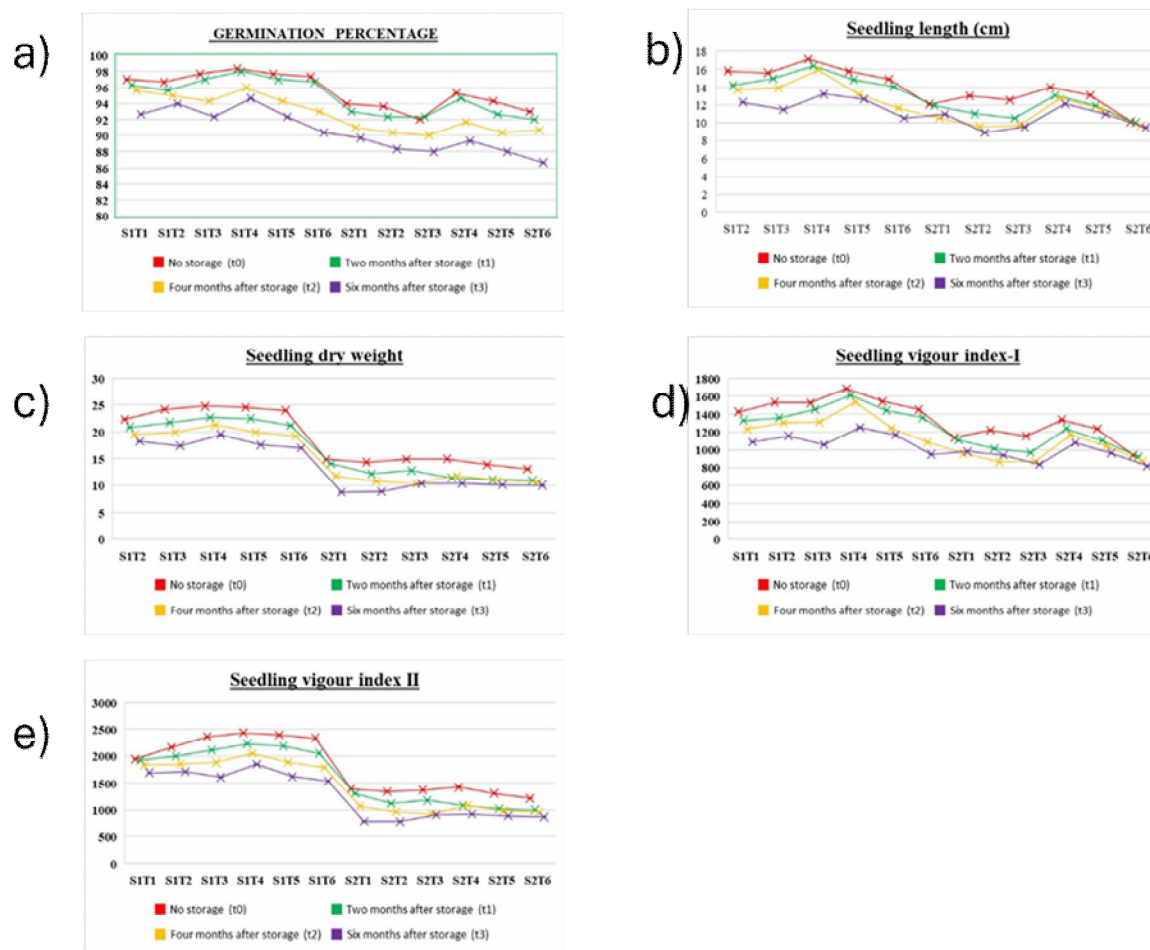


Fig. 6 : Effect of seed pelleting on seed storage and seed viability: (a) Germination percentage; (b) Seedling Length(cm); (c) Seedling Dry Weight(mm); (d) Seedling Vigour Index I; (e) Seedling Vigour Index II

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Author contributions:

JCV and YAV conceived and designed the experiments; JCV, RS and PC performed the experiments and analyzed the data; JCV, YAV and PC contributed reagents/materials/ analysis tools; JCV and RS wrote the paper; RS and YAV revised and proofread the paper.

Conflict of interest

Authors declare no competing interests.

Data availability

The data underlying this article are available in the article and its online supplementary material.

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Supplementary Table 1: Effect of sowing method treatments and their interaction effect on Crop Establishment

Characters	Initial plant population			Final plant population		
	Factor	S ₁	S ₂	Mean(T)	S ₁	S ₂
T ₁	182.33	90.00	136.17	178.67	85.00	131.83
T ₂	208.00	107.33	157.67	202.00	106.33	154.17
T ₃	183.00	112.00	147.5	179.33	105.00	142.17
T ₄	235.00	88.67	161.83	224.33	78.67	151.5
T ₅	237.67	118.33	178.00	226.33	113.00	169.67
T ₆	221.67	106.33	164.00	214.33	109.67	162.00
Mean(S)	211.28	103.78	157.53	204.17	99.61	151.89
	S.Em±	C.D. at 5%	CV %	S.Em±	C.D. at 5%	CV %
S	3.09	9.06	8.32	2.84	8.33	7.93
T	5.35	15.69		4.91	14.42	
S × T	7.56	22.19		6.95	20.40	

Supplementary Table 2: Effect of sowing method treatments and their interaction effect on Phenology

Characters	Days to maturity		
	Factor	S ₁	S ₂
T ₁	141.33	147.00	144.17
T ₂	148.00	148.67	148.33
T ₃	149.00	154.00	151.50
T ₄	123.33	148.33	135.83
T ₅	128.67	150.33	139.50
T ₆	135.67	151.33	143.50
Mean(S)	137.67	149.94	143.81
	S.Em±	C.D. at 5%	CV %
S	1.21	3.55	3.57
T	2.09	6.14	
S × T	2.96	8.69	

Supplementary Table 3: Effect of sowing method treatments and their interaction effect on Vegetative Growth

Characters	No of leaf per plant			Average leaf length			Plant height at harvesting		
	Factor	S ₁	S ₂	Mean(T)	S ₁	S ₂	Mean(T)	S ₁	S ₂
T ₁	8.87	7.13	8.00	37.69	43.35	40.52	50.20	49.18	49.69
T ₂	8.40	6.33	7.37	45.15	40.77	42.96	53.33	46.38	49.86
T ₃	7.77	6.87	7.31	47.57	40.06	43.82	52.30	46.36	49.33
T ₄	10.07	8.07	9.07	48.28	39.04	43.66	60.33	49.07	54.70
T ₅	6.67	7.80	7.23	50.63	41.63	46.13	56.27	44.33	50.30
T ₆	6.87	7.27	7.07	42.91	36.20	39.55	49.25	47.20	48.23
Mean(S)	8.11	7.24	7.68	45.37	40.18	42.77	53.61	47.09	50.35
	S.Em±	C.D. at 5%	CV %	S.Em±	C.D. at 5%	CV %	S.Em±	C.D. at 5%	CV %
S	0.22	0.64	12.11	0.80	2.36	7.97	0.78	2.28	6.56
T	0.38	1.11		1.39	4.08		1.35	3.96	
S × T	0.54	1.57		1.97	5.77		1.91	5.60	

Supplementary Table 4: Effect of sowing method treatments and their interaction effect on Bulb Development and Size

Characters	Polar diameter (mm)			Equatorial diameter (mm)			Bulb size index (mm ²)		
	Factor	S ₁	S ₂	Mean(T)	S ₁	S ₂	Mean(T)	S ₁	S ₂
T ₁	40.48	35.66	38.07	51.54	46.67	49.10	1984.29	1732.62	1858.46
T ₂	37.74	38.88	38.31	44.51	42.66	43.59	2095.52	1869.06	1982.29
T ₃	41.92	38.25	40.09	55.33	46.93	51.13	2262.87	1856.63	2059.75
T ₄	46.95	39.70	43.33	58.92	44.55	51.74	2977.42	1845.63	2411.52
T ₅	46.50	34.64	40.57	62.32	45.33	53.82	3071.78	1671.51	2371.64
T ₆	41.12	38.56	39.84	55.30	45.63	50.47	2310.54	1756.61	2033.57
Mean(S)	42.45	37.62	40.03	54.62	45.30	49.97	2450.40	1788.68	2119.54
	S.Em±	C.D. at 5%	CV %	S.Em±	C.D. at 5%	CV %	S.Em±	C.D. at 5%	CV %
S	0.662	1.94	7.02	0.87	2.55	7.39	50.81	149.02	10.17
T	1.1466	3.36		1.51	4.42		88.00	258.11	
S × T	1.6215	4.76		2.13	6.25		124.45	365.03	

Supplementary Table 5: Effect of sowing method treatments and their interaction effect on Yield Components

Characters	Number of bulb per plot			Bulb yield per plot(kg)			Average bulb weight (g)		
	S ₁	S ₂	Mean(T)	S ₁	S ₂	Mean(T)	S ₁	S ₂	Mean(T)
T ₁	143.67	84.33	114.00	4.48	3.52	4.00	33.36	52.53	42.95
T ₂	138.67	73.00	105.83	4.83	3.90	4.37	41.93	42.94	42.44
T ₃	173.67	49.67	111.67	4.30	3.09	3.69	44.75	40.79	42.77
T ₄	222.00	71.33	146.67	6.57	3.57	5.07	71.04	34.09	52.57
T ₅	221.33	53.00	137.17	6.66	3.02	4.84	59.60	37.05	48.32
T ₆	161.67	59.67	110.67	4.85	3.42	4.13	30.11	24.32	27.22
Mean(S)	176.83	65.17	121.00	5.28	3.42	4.35	46.80	38.62	42.71
	S.Em±	C.D. at 5%	CV %	S.Em±	C.D. at 5%	CV %	S.Em±	C.D. at 5%	CV %
S	3.08	9.04	10.8	0.18	0.53	17.73	1.27	3.72	12.61
T	5.34	15.65		0.32	0.92		2.20	6.45	
S × T	7.55	22.13		0.45	1.31		3.11	9.12	

Supplementary Table 6: Effect of pelleted seeds (S₁) and non-pelleted seeds (S₂), seed treatments (T) and their interaction effect on the germination percentage in onion seeds during storage

Factor	No storage (t ₀)	Two months after storage (t ₁)	Four months after storage (t ₂)	Six months after storage (t ₃)
S ₁	97.44	96.78	94.72	92.72
S ₂	93.72	92.83	90.67	88.33
S.Em±	0.31	0.31	0.40	0.44
C.D. at 5%	0.90	0.92	1.18	1.27
T ₁	95.50	94.67	93.33	91.17
T ₂	95.17	94.00	92.67	91.17
T ₃	94.83	94.67	92.17	90.17
T ₄	96.83	96.33	93.83	92.00
T ₅	96.00	94.83	92.33	90.17
T ₆	95.17	94.33	91.83	88.50
S.Em±	0.54	0.54	0.70	0.75
C.D. at 5%	NS	NS	NS	NS
S × T				
S1T1	97.00	96.33	95.67	92.67
S1T2	96.67	95.67	95.00	94.00
S1T3	97.67	97.00	94.33	92.33
S1T4	98.33	98.00	96.00	94.67
S1T5	97.67	97.00	94.33	92.33
S1T6	97.33	96.67	93.00	90.33
S2T1	94.00	93.00	91.00	89.67
S2T2	93.67	92.33	90.33	88.33
S2T3	92.00	92.33	90.00	88.00
S2T4	95.33	94.67	91.67	89.33
S2T5	94.33	92.67	90.33	88.00
S2T6	93.00	92.00	90.67	86.67
S.Em±	0.76	0.77	0.99	1.07
C.D. at 5%	NS	NS	NS	NS
CV %	1.37	1.41	1.85	2.04

Supplementary Table 7: Effect of pelleted seeds (S₁) and non-pelleted seeds (S₂) and seed treatments (T) and their interaction effect on the seedling length (cm) in onion seeds during storage.

Factor	No storage (t ₀)	Two months after storage (t ₁)	Four months after storage (t ₂)	Six months after storage (t ₃)
S ₁	15.64	14.70	13.55	11.98
S ₂	12.48	11.40	10.61	10.30
S.Em±	0.16	0.15	0.13	0.11
C.D. at 5%	0.46	0.43	0.39	0.32
T ₁	13.39	12.86	11.72	11.32
T ₂	14.43	12.59	11.62	10.6
T ₃	14.07	12.73	11.81	10.48
T ₄	15.56	14.73	14.34	12.67

T₅	14.43	13.37	12.36	11.81
T₆	12.50	12.05	10.64	9.97
S.Em±	0.28	0.25	0.23	0.19
C.D. at 5%	0.80	0.75	0.68	0.56
S × T				
S1T1	14.69	13.79	12.91	11.71
S1T2	15.81	14.19	13.71	12.32
S1T3	15.58	14.95	13.91	11.45
S1T4	17.11	16.38	15.95	13.23
S1T5	15.75	14.84	13.19	12.65
S1T6	14.89	14.07	11.65	10.50
S2T1	12.09	11.93	10.54	10.93
S2T2	13.04	10.99	9.52	8.88
S2T3	12.55	10.50	9.71	9.51
S2T4	14.01	13.08	12.73	12.11
S2T5	13.11	11.91	11.53	10.96
S2T6	10.11	10.02	9.63	9.44
S.Em±	0.39	0.36	0.33	0.27
C.D. at 5%	NS	1.06	0.97	0.79
CV %	4.79	4.83	4.75	4.20

Supplementary Table 8: Effect of pelleted seeds (S₁) and non-pelleted seeds (S₂) and seed treatments (T) and their interaction effect on the seedling dry weight in onion seeds during storage

Factor	No storage (t ₀)	Two months after storage (t ₁)	Four months after storage (t ₂)	Six months after storage (t ₃)
S₁	23.31	21.50	19.85	18.01
S₂	14.33	12.05	11.00	9.73
S.Em±	0.24	0.21	0.17	0.13
C.D. at 5%	0.71	0.62	0.50	0.37
T₁	17.46	17.01	15.44	13.52
T₂	18.32	16.51	15.10	13.54
T₃	19.54	17.25	15.13	13.89
T₄	19.85	17.03	16.54	14.93
T₅	19.20	16.76	15.46	13.84
T₆	18.52	16.06	14.89	13.51
S.Em±	0.42	0.37	0.29	0.22
C.D. at 5%	1.23	NS	0.86	0.64
S × T				
S1T1	20.05	19.94	19.15	18.29
S1T2	22.32	20.88	19.52	18.23
S1T3	24.19	21.75	19.96	17.44
S1T4	24.77	22.69	21.30	19.53
S1T5	24.53	22.49	19.97	17.57
S1T6	23.99	21.24	19.21	17.02
S2T1	14.87	14.07	11.74	8.75
S2T2	14.32	12.15	10.67	8.85
S2T3	14.89	12.75	10.29	10.34
S2T4	14.94	11.37	11.78	10.34
S2T5	13.87	11.04	10.94	10.11
S2T6	13.05	10.89	10.57	9.99
S.Em±	0.59	0.52	0.42	0.31
C.D. at 5%	1.74	1.52	NS	0.90
CV %	5.47	5.37	4.68	3.85

Supplementary Table 9: Effect of pelleted seeds (S₁) and non-pelleted seeds (S₂) and seed treatments (T) and their interaction effect on the seedling vigour Index-I in onion seeds during storage

Factor	No storage (t ₀)	Two months after storage (t ₁)	Four months after storage (t ₂)	Six months after storage (t ₃)
S₁	1524.16	1423.38	1284.41	1111.54
S₂	1170.39	1059.68	962.70	910.67

S.Em±	14.33	14.97	13.45	10.04
C.D. at 5%	41.83	43.71	39.26	29.29
T₁	1280.63	1218.62	1096.47	1032.93
T₂	1374.78	1185.75	1081.65	970.67
T₃	1338.34	1210.13	1092.64	946.88
T₄	1509.09	1421.39	1349.04	1166.36
T₅	1386.49	1272.21	1142.63	1066.12
T₆	1194.33	1141.08	978.91	883.67
S.Em±	24.82	25.94	23.30	17.38
C.D. at 5%	72.44	75.70	68.00	50.74
S × T				
S1T1	1424.97	1328.22	1233.79	1086.00
S1T2	1528.27	1357.17	1302.27	1157.39
S1T3	1521.83	1450.55	1311.51	1057.14
S1T4	1682.94	1604.76	1530.86	1251.97
S1T5	1538.27	1439.60	1243.96	1167.53
S1T6	1448.69	1360.00	1084.10	949.19
S2T1	1136.28	1109.02	959.14	979.86
S2T2	1221.30	1014.34	861.04	939.97
S2T3	1154.84	969.71	873.78	836.63
S2T4	1335.25	1238.02	1167.21	1080.74
S2T5	1234.71	1104.83	1041.29	964.70
S2T6	939.97	922.16	873.71	818.16
S.Em±	35.10	36.68	32.33	24.58
C.D. at 5%	102.45	107.07	96.17	71.75
CV %	4.51	5.12	5.08	4.21

Supplementary Table 10: Effect of pelleted seeds (S₁) and non-pelleted seeds (S₂) and seed treatment(T) and their interaction effect on the seedling vigour index II in onion seeds during storage.

Factor	No storage (t ₀)	Two months after storage (t ₁)	Four months after storage (t ₂)	Six months after storage (t ₃)
S₁	2271.92	2081.22	1880.78	1671.15
S₂	1343.21	1117.50	997.20	859.40
S.Em±	24.04	19.17	16.73	13.03
C.D. at 5%	70.18	55.95	48.84	38.02
T₁	1671.36	1614.42	1450.21	1239.33
T₂	1749.98	1559.26	1408.93	1248.13
T₃	1866.64	1643.02	1404.73	1260.10
T₄	1929.07	1650.48	1562.78	1386.00
T₅	1853.42	1601.85	1435.65	1255.84
T₆	1774.92	1527.14	1371.65	1202.23
S.Em±	41.64	33.20	28.98	22.56
C.D. at 5%	121.56	NS	84.59	65.85
S × T				
S1T1	1945.15	1921.05	1832.30	1693.97
S1T2	2157.33	1997.47	1854.53	1714.53
S1T3	2362.25	2109.89	1883.27	1610.58
S1T4	2435.18	2224.56	2045.05	1848.29
S1T5	2396.19	2181.13	1883.77	1621.53
S1T6	2335.40	2053.21	1785.75	1537.99
S2T1	1397.57	1307.80	1068.12	784.70
S2T2	1342.63	1121.05	963.33	781.73
S2T3	1371.03	1176.15	926.19	909.61
S2T4	1422.97	1076.39	1080.51	923.71
S2T5	1310.64	1022.57	987.52	890.15
S2T6	1214.44	1001.06	957.55	866.47
S.Em±	58.89	46.95	40.98	31.90
C.D. at 5%	171.91	137.06	NS	93.13
CV %	5.64	5.09	4.93	4.37