Review Article

Effect of Pre-sowing seed treatments and synthetic polymer coating on seed quality and storability in Redgram (*Cajanus cajan. L*.)

Abstract

A successful agriculture depends on high-quality seed, which is a fundamental and important ingredient. In particular under unfavorable environmental conditions like drought, pre-sowing seed treatment such as seed coating and seed priming could boost seed germination and seedling vigour. The coating agents often include plant growth regulators, micro-fertilizers, pesticides, and insecticides. The present investigation was carried out to assess the impact of seed treatment and polymer coating on seed quality parameters of pigeon pea variety PRG 176 from 2018 to 2021 at Seed Research and Technology Centre, Rajendranagar, Hyderabad. The trial was laid out in a randomized block design with four replications. Freshly harvested redgram variety Ujwala Seeds were treated with Seed hardening with $ZnSO_4$ @100ppm + Seed coating with Polymer 3ml/kg + Bavistin 2g/kg + Imidacloprid 1ml/kg + Pseudomonas fluorescens 10 g/kg + Rhizobium in different combinations. The treated seeds were shade dried, packed in gunny bags, and stored at room temperature to assess the impact of various treatments on seed quality metrics under ambient storage conditions. The results of bimonthly observations on seed quality parameters showed that there were substantial differences between the treatments for the characters under study. The T7 treatment recorded the highest germination percentage (98 and 70.67), speed of emergence (12.1 and 10.1), electrical conductivity (0.169 and 0.292), seedling shoot length (14.9 and 8.65cm), seedling root length (14.5 and 8.52cm), seedling length (29.4 and 17.17cm), seedling fresh weight (5.55 and 2.5g), seedling dry weight (0.40 and 0.21g), seed vigour index-I (2881 and 1213), seed Vigour Index-II (53.9 and 14.84) over other treatments under study at the initiation of storage studies (2MAS) and at 28 months of storage period respectively. The current study's findings showed that T7 treatment greatly outperformed all other treatments for all characters, maintaining an optimal germination percentage (70.67%) even up to 28 months of storage under ambient storage conditions.

Keywords: Redgram, seed priming, synthetic polymer coating, seedling quality parameters, seed storage

1. Introduction

Pigeonpea [Cajanus cajan (L.)] is the second-most significant pulse crop after chickpea that is highest in protein content in India. It grows in tropical and subtropical climates and is said to have originated in peninsular India and is particularly drought tolerant because of its extensive root system. The majority of the world's pigeonpea cultivation and consumption occurs in underdeveloped nations. The world's biggest producer and consumer of pulses is India.

Successful agriculture depends on quality seed, and it is a prerequisite that every seed be easily germinable and generate a robust seedling to provide a better output [1]. The seed used for planting should be free of pests and diseases because seed health is a crucial component of seed quality. Redgram has a high deal of environmental adaptability, however the occurrence of pests and diseases may lead to lower yield and quality. Prior to planting, seeds are treated with a chemical, usually an antibacterial, fungicidal, or insecticidal agent, to provide a low-cost measure of protection against pests and diseases [2]. Seed treatment, which is beneficial for crop growth and yield in addition to disease prevention, is applied to many crops for a variety of reasons. A fungicide called bavistin is used to guard seed and crops against fungal infections. Imidacloprid, a systemic pesticide from the neonicotinoid chemical family, works by specifically impeding insects' microtinergic neural pathways [3].

Seed polymer coating is the most promising of the many novel production methods known as "seed enhancement techniques" that have been developed by numerous scientists across the world [4]. These methods include seed coloration, seed pelleting, seed fortification, seed infusion, and many others. Seed coating is the direct application of beneficial material to create a thin, uniform covering without changing the seed's size or shape. It allows for the inclusion of all necessary elements, such as herbicides, plant growth promoters, hydrophobic/hydrophilic compounds, nutrients, inoculants, protectants, and nutrients [5]. In addition to ensuring dust-free handling of treated seed, seed coating with polymer enhances the chemical's adhesion to the seed. Functionalized polymers were utilised to improve the efficacy of pesticides and herbicides, enabling the administration of precise and uniform chemical dosages as well as to indirectly preserve the environment by lowering pollution and cleaning-up existing pollutants [6]. The seed's health can be improved by using polymer in addition to fungicides and insecticides.

2. Material and Methods

The experiment was conducted during 2018-19 to 2020-21 at Seed Research and Technology Centre, Rajendranagar, Hyderabad. The experiment consisted of six seed treatments with one control and was laid out in a randomized block design with four replications. Seeds of Pigeonpea cultivar PRG 176 was used for the study. The treatments included

T1: Control + Rhizobium,
T2: Bavistin 2g/kg + Rhizobium,
T3: Seed hardening with $ZnSO_4$ 100ppm (soaking in 1/3 volume of seed to solution ratio for 3h) + Rhizobium.
T4: Seed hardening with $ZnSO_4$ 100ppm+ Seed coating with Polymer 3ml/kg + Bavistin 2g/kg + Imidacloprid 1ml/kg + Rhizobium
T5: Seed coating with Polymer 3ml/kg + Bavistin 2g/kg + Imidacloprid 1ml/kg + Rhizobium
T6: Seed coating with Polymer 3ml/kg + Bavistin 2g/kg + Imidacloprid 1ml/kg + Pseudomonas fluorescence 10 g/kg + Rhizobium
T7: Designer seed (Seed hardening with $ZnSO_4$ 100ppm + Seed coating with Polymer 3ml/kg + Bavistin 2g/kg + Imidacloprid 1ml/kg + Pseudomonas fluorescence 10 g/kg + Rhizobium).

The seeds are treated with bacterial cultures also, so the order in which seed treatments imposed were as follows
i) Chemical treatments
ii) Insecticide and fungicide treatments
iii) Special treatments

The process of "seed hardening" involves physiologically preparing the seed by hydrating it to withstand drought under conditions of rainfed growth. Dissolve 1000mg salt in 1000ml water to make 100ppm zinc sulphate solution. The seeds were restored back to their natural moisture content (8%) after soaking the seed in 100ppm ZNSO4 solution for 4 hours.

Polykote, a liquid polymer created by Incotec Company Ltd. in Pune, was used to coat seeds.Two kilogram gram of seeds were taken for each treatment in a polythene bag, initially and as per the serial order; treatments were imposed. The polythene bag was closed tightly trapping air in it to form a balloon, it was shaken erratically until all the seeds were evenly coated. The seed was coated with polymer @ 3 g kg-1 seed for the treatments T5, T6, T7, and the other treatments are left uncoated without polymer. Extreme attention was taken to ensure uniformity in coating while seed coating. The treated seeds were stored at SRTC under ambient circumstances (mean temperature 25+ 20 C and RH 75%) along with the control seeds (T0) after being shade-dried to their original moisture content of 8%.

For each of the experiment's treatments, 4 replicates were used in the lab test. According to the methods and procedures outlined by ISTA in 2016 (7), observations on various seed quality parameters *viz.,* seed germination (%), speed of germination, electrical conductivity(dsm^{-1}), seedling root length (cm), seedling shoot length (cm), and seedling length (cm), seedling fresh weight (g), seedling dry weight (g), and seedling vigour index I and seedling vigour index II, were recorded. According to Panse and Sukhatme (1985) [8], a completely randomized design was used to statistically assess the mean data from the laboratory tests. Every time a "F" test indicated that one of the several seed quality measures under examination was significantly different from the others, the crucial differences were determined at a 5% level of probability.

Germination percentage (%): Up until there was no more germination, daily germination counts were observed. After the test time, the number of normal seedlings was counted, and the percentage of germination was determined using the following formula:

Germination percentage (%) = Number of normal seedlings/ Total number of seed sown x 100

Speed of germination: The following formula was used to determine the rate of germination:
Speed of germination = N1/T1 + N2/T2 + N3/T3 + ------- + Nx/Tx
Where, N= Number of seed germinated in days 'T'

Electrical conductivity (dsm-1): 25 seeds were soaked in 50 ml of deionized water for 8 hours and the electrical conductivity was determined using a conductivity meter.

Shoot length (cm): After the germination count, ten normal seedlings from each treatment and replication were chosen at random to measure the shoot length. From the tip of the primary leaf to the base of the hypocotyl, the shoot length was measured, and the mean shoot length was given in cm.

Root length (cm): Using a scale, the length of the root was measured from the tip to the base of the hypocotyl, and the mean root length was given in centimeters. The root length was measured on the same seedlings that were previously used to record shoot length parameter.

Seedling length (cm): The average seedling length in centimeters was determined by adding the root and shoot lengths of ten seedlings.

Seedling fresh weight (g): An electronic weighing balance was used to record the fresh weight of ten representative seedlings that were utilised to measure the shoot and root lengths. Per seedling, the average weight was computed and given in grams.

Seedling dry weight (g): For the fresh weight measurement, ten representative seedlings were collected in butter paper packets and kept in an oven set to 75°C for 48 hours. The dried seedlings' weight was measured using an electronic weighing balance after chilling, and the average weight was determined and expressed in grams per seedling.

The following formulas were used to calculate the seedling vigour index-**I** and **II** as recommended by Abdul-Baki and Anderson (1973) [9]:
Seedling vigour index-I = Germination (%) × Seedling length (cm)
Seedling vigour index-II = Germination (%) × Seedling dry weight (g).

3. Results and Discussion

The results show that all features under investigation were impacted by the treatments, and treated versus control seeds showed a highly significant differences during bimonthly lab tests conducted. All seedling characteristics, including germination percentage (%), speed of germination, electrical conductivity(dsm^{-1}), shoot length (cm), root length (cm), seedling length (cm), seedling fresh weight (g), seedling dry weight (g), seed vigour index **I** and seed vigour index **II** of the seedlings were significantly impacted by the T7 treatment (seed hardening with $ZnSO_4$ 100ppm + seed coating with Polymer 3ml/kg + bavistin 2g/kg + imidacloprid+ Pseudomonas fluorescence 10 g/kg + Rhizobium) (Table 1).

Table 1. Analysis of variance for laboratory studies of redgram seed after 28 months of storage period

S.No	Character	Mean sum of squares	
		Treatment	Error
		df=18	df=27
1	Germination (%)	52.45	3.52
2	Speed of germination	8.11	1.01
3	Electrical conductivity	4.75	2.01

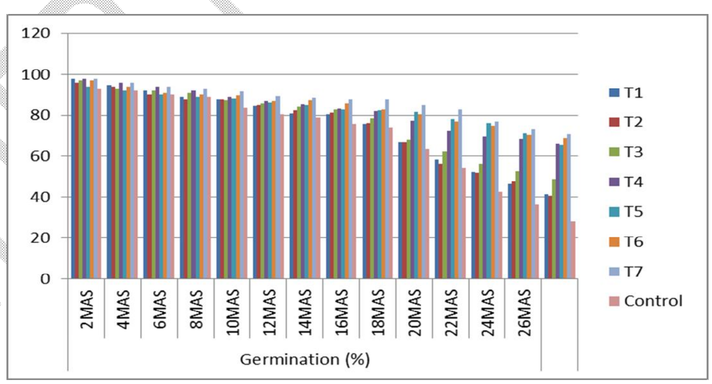
4	Seedling shoot length (cm)	21.98	1.88
5	Seedling root length (cm)	21.35	1.96
6	Seedling length (cm)	73.21	6.59
7	Seedling fresh weight (g)	0.11	0.04
8	Seedling dry weight (g)	0.01	0.001
9	Seedling vigour index I	657364.55	31732.62
10	Seedling vigour index II	202.43	72.51

Results on different parameters of seed quality, including seed germination (%), speed of germination, electrical conductivity (dsm-1), and seedling shoot length (cm),seedling root length (cm), seedling length (cm), seedling fresh weight (g), seedling dry weight (g), seedling vigour index I and seedling vigour index II are presented as follows(Table 2 and 3).

1. Germination percentage (%)

The maximum germination (%) (98.00) was recorded in T7 (Seed hardening with $ZnSO_4$ 100ppm + Seed coating with Polymer 3ml/kg + Bavistin 2g/kg + Imidacloprid 1ml/kg + Pseudomonas fluorescence 10 g/kg + Rhizobium), while minimum (93) germination (%) was observed in T0 (Control) at initiation of storage studies. After 28 months after storage (MAS); T7 recorded 70.67% while all other treatments recorded below minimum seed certicication standards. The results are in agreement with Satyabhama et al. [10] observed significantly higher seed germination In groundnut with polymer coating @ 4 ml kg-1 seed and came to the conclusion that the increase in germination may be caused by the hydrophilic nature of the polymer, which has increased imbibition rate, led to faster cell activation, enhancement of mitochondrial activity, formation of more high energy compounds, and led to the creation of more essential biomolecules, which were made available.

Fig.1: Influence of seed treatment and polymer coating on germination of Redgram



2. Speed of germination.

The highest speed of germination was recorded in T7 (22.5 and 10.2) at 2MAS and 28MAS respectively. The hydrophilic property of the polymer, which led to faster water intake and quicker radical emergence, is thought to be the cause of the polymer coated seed's increased germination speed. The results are in line with [11, 12].

3. Electrical conductivity

The reflection of seed degeneration coupled with changes in the membranes of aged seeds is one of the hypothesised causes for loss of vigour and viability during ageing [13]. The electrical conductivity in the current investigation was generally lowest in designer seeds (0.169) and highest in controls (0.205) and after 28 MAS (0.292 and 0.377) in T7 and control. This suggests that the repair mechanism activated by treating seeds with polymer coated seeds is in operation.

The results of the current investigations showed that the polymer-coated seeds often degenerated at a slower phase than controls, which was manifested in higher germination than controls. This is mostly because coated seeds kept up their high vigour since they deteriorated less quickly than control seeds did. In conclusion, it was discovered that polymer feeding at 3g kg-1 with 5 ml water was successful in halting deteriorative senescence. Similar results were obtained by Sujatha et al. [14] found limited electrical conductivity with polymer coating in redgram (0.170 and 0.189 at 2MAS and at 4MAS), and a similar trend was also seen in greengram (0.184 and 0.188 at 2MAS and at 4MAS).

Table 2: Mean performance of seeds for 10 seedling characters at initiation of storage studies in Redgram

Treatments	Germination (%)	Speed of germination	Electrical conductivity (dsm-1)	Shoot length (cm)	Root length (cm)	seedling length (cm)	Fresh wt.(g)	Dry Wt.(g)	SVI-1	SVI-1
T1	98	17.0	0.199	12.6	12.8	25.4	4.59	0.53	2489	51.94
T2	96	18.6	0.192	12.2	12.7	24.9	4.83	0.48	2390	46.08
T3	97	18.0	0.189	12.8	14.8	27.6	5.1	0.49	2677	47.53
T4	98	20.3	0.187	12.4	13.9	26.3	4.75	0.52	2577	50.96
T5	94	19.3	0.185	12.6	12.3	24.9	5.42	0.48	2341	45.12
T6	97	21.0	0.182	14.1	14.5	28.6	5.38	0.49	2774	47.53
T7	98	22.5	0.169	14.9	14.5	29.4	5.55	0.55	2881	53.9
Control	93	16.3	0.205	11.1	11.4	22.8	4.01	0.4	2120	37.2
Grand mean	96.38	21.86	0.19	12.88	13.36	26.24	4.95	0.49	2531.13	47.53
F Test	S	S	S	S	S	S	S	S	S	S
CD at 5%	0.72	0.51	0.16	0.68	0.42	0.69	0.75	0.43	52.83	12.45
SE(m)	1.98	1.45	1.66	1.52	1.26	1.94	0.08	0.04	165.01	42.56

4. Seedling shoot length (cm)

A statistical analysis of the seedling shoot length data revealed a substantial difference between the treatments. The control seeds recorded the lowest value (11.1 and 5.73 cm at 2MAS and 28MAS), whereas designer seedlings (T7 treatment) had the longest shoots (14.9 and 8.65 cm at 2MAS and 28MAS) respectively.

5. Seedling root length (cm)

At two months of storage and 28 months after storage, polymer-coated seeds recorded longer roots (14.5 and 8.52 cm) than controls (11.4 and 5.96 cm). Data on seedling root length were statistically evaluated and substantial differences across the treatments were discovered.

6. Seedling length (cm)

The Maximum seedling length (29.4cm) was recorded in T7 (Designer seeds), while minimum (22.8cm) seedling length was observed in T0 (Control) at initiation of storage studies. After 28 months of storage studies, the same pattern persisted with the T7 treatment recording the longest seed length of 17.17 cm, compared to the control's 11.69 cm.

The early emergence and growth of the seedlings could be attributed to the increased synthesis and activity of hydrolytic enzymes during the early stages of germination and effective mobilisation of the available food stores in the seeds. Similar results were noticed by Rakesh et al. [15].

Table 3: Mean performance of pegionpea seeds for 10 seedling characters after 28 months of storage

Treatments	Germination (%)	Speed of germination	Electrical conductivity (dsm-1)	Shoot length (cm)	Root length (cm)	seedling length (cm)	Fresh wt.(g)	Dry Wt.(g)	SVI-1	SVI-1
T1	41.33	8.1	0.313	5.76	6.11	11.87	1.4	0.152	491	6.28
T2	40.67	8.3	0.351	5.98	6.02	12.00	1.5	0.169	488	6.87
T3	48.67	8.5	0.301	6.13	6.15	12.28	1.6	0.170	598	8.27
T4	66.00	8.6	0.298	5.95	6.89	12.84	1.9	0.185	847	12.21
T5	65.33	9.9	0.296	8.04	8.21	16.25	2.1	0.188	1082	12.28
T6	68.67	9.8	0.24	7.99	8.5	16.49	2.2	0.192	1132	13.18
T7	70.67	10.2	0.292	8.65	8.52	17.17	2.5	0.210	1213	14.84
Control	28.00	7.4	0.377	5.73	5.96	11.69	1.01	0.110	327	3.08
Grand mean	53.67	8.85	0.31	6.78	7.05	13.82	1.78	0.17	772.25	9.63
F Test	S	S	S	S	S	S	S	S	S	S
CD at 5%	2.55	3.12	0.13	1.54	1.96	1.83	0.25	0.31	12.32	8.11
SE(m)	2.21	1.99	0.28	2.01	1.98	0.87	0.04	0.02	215.55	12.83

7. Seedling fresh weight (g)

The highest seedling fresh weight (5.55g) was recorded in T7, while least (4.01g) seedling fresh weight was observed in T0 (Control).The treatment T6 (T7- Seed hardening with $ZnSO_4$ 100ppm) is statistically at par with T7 (seed hardening with $ZnSO_4$ 100ppm + seed coating with Polymer 3ml/kg + bavistin 2g/kg + imidacloprid+ Pseudomonas fluorescence 10 g/kg + Rhizobium). These results are in line with suchit tiwari and Chaurasia [16].

8. Seedling dry weight (g)

The highest seedling dry weight (0.55g) was recorded in T7 (seed hardening with $ZnSO_4$ 100ppm + seed coating with Polymer 3ml/kg + bavistin 2g/kg + imidacloprid+ Pseudomonas fluorescence 10 g/kg + Rhizobium), while least (0.40g) seedling dry weight was observed in T0 (Control). The treatment T6 is statistically at par with T7 treatment under study.

Production of dry matter increased in direct proportion to an increase in seedling growth. These findings, are in agreement with Arvind and Yadav [17].

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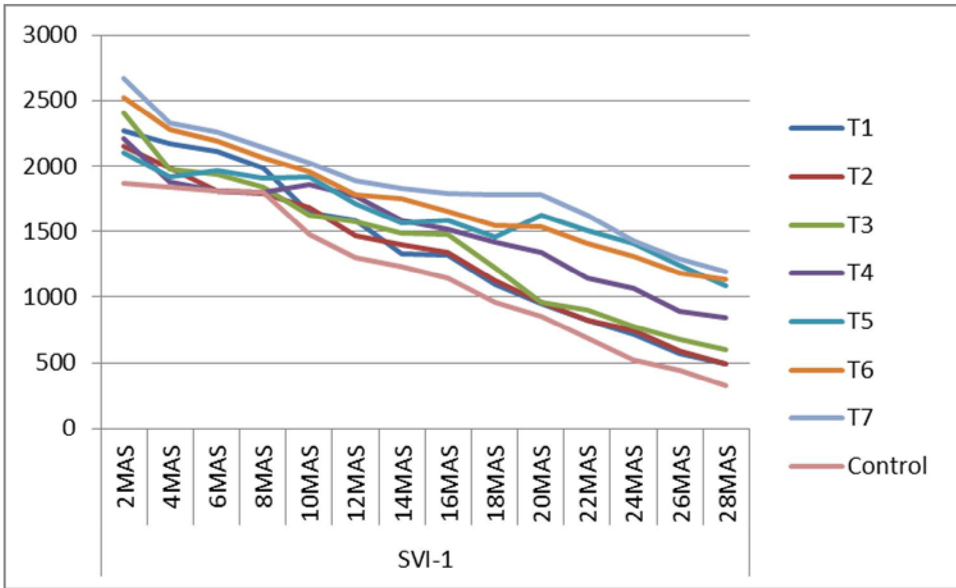
9. Seed vigour index I

The T7 (Designer seed) seedlings had the greatest seedling vigour index I score (2881), whereas the T0 (Control) seedling had the lowest (2120) in terms of seedling vigour, Rakesh et al. [18] found a considerable variation.

A statistical analysis of the seed vigour index I data revealed a substantial difference between the treatments. The improved germination and seedling growth traits are the primary causes of the higher vigour index I.

Fig.2: Influence of seed treatment and polymer coating on seed vigour index-I of Redgram



10. Seed vigour index II

The highest seedling vigour index II (53.0) was recorded in T7 (Designer seeds), while least (37.2) seedling vigour index II was observed in T0 (Control) at initiation of storage studies (2MAS). The early emergence and growth of the seedlings, which led to the elevated vigour index II, were primarily the result of successful mobilization of the seeds' food reserves. Production of dry matter grew proportionately to an increase in seedling growth. Additionally, the seed vigour was improved by an overall increase in seedling development and germination characteristics.

Although germination, root length, shoot length, and electrical conductivity did not significantly improve with polymer coating right away, polymer coated seeds germinated more frequently (70.2%) than control seeds during natural ageing (28.00) in Fig1. Polymer-coated seeds were successful in reducing degradation and producing higher values of seed vigour index I (before and after natural ageing) in Fig 2. Sherin Shusan and Bharnthi [19] observed similar results in maize, Balaraju and Prashanth Kumar [20] in cotton, and Saloni et al. [21] in greengram.

The results of the current study showed that T7 (seed hardening with $ZnSO_4$ 100ppm + seed coating with Polymer 3ml/kg + bavistin 2g/kg + imidacloprid+ Pseudomonas fluorescence 10 g/kg + Rhizobium) had the highest germination percentage (92.75), seedling root length (11.28 cm), seedling shoot length (3.19 cm), and seedling length (14.47 cm). T7 (Polymer coating@ 3g kg-1 seed + Seed treatment with Thiram @ 2g kg-1 seed) yielded the highest seedling fresh weight (1.47g), seedling dry weight (0.40g), seedling vigour index I (1341.99), and seedling vigour index II (37.10) at 28 months after storage.

4. Conclusion

Different combinations of insecticide, fungicide, seed hardening agent, bio inoculants, and polymer coating on pegionpea seeds are successful, although treatment T7 demonstrates greater effectiveness on germination percentage (94.75%) and all other physiological parameters. Additionally, seed treatments have a positive impact on germination, and seed hardening produced superior outcomes. Finally, it is determined that the various treatments, combined with polymer coating, can be employed to improve the seed quality in pigeonpea.

5. Future scope

Hopes for the future of agriculture are raised by nanotechnology, the science of manipulating the tiniest possible particles. Recently, the utilization of these components in nanoparticle form has become more significant, particularly for improving seed quality in a few crops. To determine the impact of seed polymerization with Zn and Fe nanoparticles on seedling characteristics of pigeonpea seed is to be made in this context. The current findings are limited to laboratory tests and on single cultivar. Therefore, it may need additional testing on other cultivars with various seed treatments and polymer combinations under both field and laboratory evaluation studies in order to be delivered as recommendations.

References

1. Ananthi M, Selvaraju P, Srimath P. Effect of seed treatment on seed and seedling quality characters in redgram cv. CO (Rg) 7. International Journal of Science and Nature. 2015; 6(2):205-208
2. Ilieva A, Vasileva V. Effect of presowing treatment of seed with insecticides on parameters related to nodulation and nitrate reduction in soybean [*Glycine max* (L.) Merr.]. Journal of Central European Agriculture. 2014; 15(2):23-32
3. Kumar K, Singh J. Effect of fungicides on seed borne fungi in sesame during storage. Seed Research. 1984; 12: 100-111.
4. Kumar M, Kumar A, Kumar R, Yadav SK, Yadav R, Kumar J. Effect of seed enhancement treatment on field performance of chickpea (*Cicer arietinum* L.). Journal of Applied and Natural Science. 2015; 7(2):557–561.
5. Delouche JC, Baskin CC. Accelerated ageing techniques for predicting the relative storability of seed lots. Seed Science and Technology.1973; 12: 427-452.
6. Ekebafe LO, Ogbeifun DE, Okieimen FE. Polymer applications in agriculture. Biochemistry. 2011; 23(2):81- 89.
7. ISTA. International Rules for seed testing. 2016; 13: 209-355.
8. Panse M, Sukhatme K. Statistical Methods for Agricultural Workers. Indian Council of Agriculture Research, New Delhi. 1978, 48-67.
9. Abdul-Baki AA, Anderson JD. Vigour determination in soybean seed by multiple criteria. Crop Science. 1973; 13(1):630-633.
10. Satyabhama, Macha SI, Vasudevan SN, Shakuntala, Khan NMH. Effect of seed coating polymer on seed quality in groundnut (*Arachis hypogaea* L.). Journal of Farm Sciences. 2016; 29(1):106-107.
11. Jayarambabu B, Siva Kumari K, Venkateswara Rao, Prabhu YT. Germination and Growth Characteristics of Mungbean Seeds (*Vigna radiata* L.) affected by Synthesized Zinc Oxide Nanoparticles, International Journal of Current Engineering and Technology. 2014; 4(5):2347-5161.
12. Prashanth Reddy B, Bineeta MB, Yaswanth Krishina R.Effect of Polymer Seed Coating and Seed Treatment on Seed Quality Parameters and Yield Attributing Characters of Hybrid Maize (Zea mays L.). Int.J.Curr.Microbiol.App.Sci. 2019; 8(08): 1175-1182.
13. Kumar M, Kumar A, Kumar R, Yadav SK, Yadav R, Kumar J. Effect of seed enhancement treatment on field performance of chickpea (*Cicer arietinum* L.). Journal of Applied and Natural Science. 2015; 7(2):557–561.
14. Sujatha K, Ramamoorthy K. Seed quality enhancement in redgram and greengram by polymer coating. International Journal of Agricultural Sciences. 2009; 5(1):297-298.
15. Rakesh P, Prasad RD, Devi GU, Bhat BN. Effect of biopolymers and synthetic seed coating polymers on castor and groundnut seed. International Journal of Pure and Applied Biosciences. 2017; 5 (4): 2043-2048
16. Suchit Tiwari, Chaurasia AK. Effect of organic priming on seed germination behavior and vigour of chick pea (Cicer L.) Journal of Pharmacognosy and Phytochemistry. 2018; 7(4): 1064-1067.
17. Arvind K, Yadav RDS. Effect of seed priming through chemicals on seed enhancement in chick pea (*Cicer arietinum* L.). International Journal of Chemical Studies. 2019; 7 (3): 3390-3393.
18. Viabhav P, Prashant Kumar R, Bineeta MB, Srivastav DK. Influence of halo priming and organic priming on germination and seed vigour in black gram (*Vigna mungo* L. seeds). Journal of Pharmacognosy and Phytochemistry. 2017; 6(4): 537-540
19. Sherin Shusan, Bharathi A. Film technology on seed quality and shelf life of maize. Abstr XII-National Seed Seminar ANGRAU, Hyderabad. 2006; 24-26 Pg. no. 84.
20. Bala Raju B, Prashant Kumar R. Studies on effect of polymer seed coating, nanoparticles and hydro priming on seedling characters of Pigeonpea (*Cajanus cajan L.)* seed. Journal of Pharmacognosy and Phytochemistry. 2017; 6(4): 140-145
21. Saloni Bahri, Smriti Sharma Bhatia Sushma Moitra, Ninadini Sharma, Ruchi Bhatt, Nivedita Sinha Borthakur, Rohini Agarwal. Jain Influence of silver nanoparticles on seedlings of (*Vigna radiate* L.) R. Wilczek, Journal of Undergraduate Research and Innovation. 2016; 2(1)142- 148.