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Impact of bio-pesticides and storage containers on lentil seed preservation and pre-sowing fungal treatment

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Abstract
We conducted a study to determine the most effective method of preserving lentil seeds for future sowing. The experiment involved six different types of storage containers: cotton cloth bags, tin containers, earthen pots, plastic containers, polythene bags, and gunny bags. We also used four plant extracts: Piper betel (Betel leaf), Azadirachta indica (Neem), Allium indica (Garlic), and Swietenia mahagoni (Mahagani). We measured the vigor index and germination percentage at 2, 4, and 6 months after storage, and then documented the fungal connection. In a separate experiment, we conducted a pre-sowing seed treatment using botanicals and biological agents such as garlic (5% w/v aqueous solution), datura (5% w/v aqueous solution), mehogoni leaf extract (5% w/v aqueous solution), mehogoni seed extract (5% w/v aqueous solution), and fern leaf extract (5% w/v aqueous solution). We treated the seeds with various substances to suppress seed-borne fungi, including ash coating (10 g kg-1 seed), fresh cow dung coating, a solution of cow urine (5% v/v water), Provax-200 (2 g kg-1 seed), and an untreated control group. In terms of germination, vigor index, and seed infection, the lentil seeds stored in a polythene bag with neem leaf extract significantly outperformed the other treatments. We found that the durability of lentil seeds significantly decreased as the storage time increased. The seed treatment fungicide Provax-200 had a significant impact on lowering the presence of fungus (by 87.41%) and boosting the germination percentage (by 39.49%) of lentil seeds.
Keywords: Lentil seed preservation, Storage containers, Plant extracts, Seed germination, Seed-borne fungi, Pre-sowing treatment

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INTRODUCTION
In Bangladesh, pulses are a crucial component of the daily diet, serving as a primary source of protein (Das et al., 2016). Among the several pulses available, lentils are the most widely consumed, surpassing mung beans, chickpeas, and black grams in popularity. In our country, the average daily consumption of lentils is only 4 grams per person. However, the World Health Organization (WHO) recommends a daily intake of 45 grams of pulses per person (Rahman et al., 2013). The principal area for lentil cultivation in the Mid-Western region of Bangladesh includes Jashore, Jhenidah, Magura, Faridpur, Rajbari, Kushtia, Chuadanga, Madaripur, Meherpur, and Pabna districts (Afzal et al., 1999).

Seeds generally degrade quickly when exposed to high temperatures and relative humidity during storage, which creates ideal conditions for the growth of pests and fungi that affect the seeds. This negatively affects the germination of the seeds. Farmers store the majority of seeds sown in the field (98.85%), while BADC supplies a small portion (1.15%). However, the storage conditions for the BADC-supplied seeds sometimes lack sufficient temperature and moisture control. Seeds are the primary and crucial component in crop production. The use of high-quality seeds significantly enhances agricultural productivity. The inadequate storage conditions led to a

decline in the quality of the seed, as reported by Fakir et al. (2007), which ultimately resulted in a low yield. In Bangladesh, the lentil yield is comparatively low (0.963 t ha-1) compared to other countries such as Australia (1.50 t ha-1), Canada (1.80 t ha-1), and Ethiopia (1.22 t ha-1) (BBS 2011, Matny 2015, Wang 2017) due to a scarcity of high-quality seeds (Kashem et al., 2005).

Proper storage conditions and seed maintenance are critical factors in obtaining high-quality seeds for sowing. The optimal storage conditions and proper care are crucial for preserving the high germination rate and seed vigor for the following year's planting. Currently, our country lacks sufficient supplies and facilities for seed storage at the farmer's level, despite its crucial role in crop production. Applying fungicides to seeds is an important method in crop management to prevent seed-borne diseases and ensure the production of healthy plants (Mortuza et al., 2002). The application of fungicidal treatment not only protects seedlings from soil-borne diseases but also improves plant development and vitality in lentils (Kovacicova, 1970). Pesticide application in the field is a highly successful and universally endorsed approach to disease control. Lentil farmers and researchers widely utilize chemical fungicides due to their convenience and efficacy in controlling field diseases. Several studies (Ahmed, 2011; Huq and Zaman, 2007; Gupta et al., 1996; Bakr and Ahmed, 1992; Iqbal et al., 1989) support this.

The use of plant extract for controlling seed-borne fungi is not as widely practiced as chemical control. However, several studies have shown that botanical extract can effectively control seed-borne fungi in other crop diseases (Bhatiya et al., 2007; Islam, 2005; Bowers and Locke, 2000; Sharma and Gupta, 1998). Plant extract is applied to treat seeds. Biological agents are more cost-effective, environmentally benign, and readily accessible compared to chemical agents (Karuna et al., 2012; Khan et al., 1999).

Recent studies highlight the potential of seed priming and biological treatments to improve seedling growth and resistance to pathogens. Anwar et al. (2020) demonstrated that seed priming enhances growth and nutrient content in cucumber seedlings. Damalas et al. (2019) showed hydropriming's positive effects on seed germination and field performance in faba beans. Devika et al. (2021) emphasized seed priming as a supplement in integrated resource management. Feng et al. (2016) explored the relationship between plant canopy characteristics and photosynthetic productivity in cotton, while Jain et al. (2012) highlighted microbial consortium-mediated defense in pea plants.

This research aims to determine the optimal technique for storing and treating seeds to preserve their long-term viability and health.

MATERIALS AND METHODS

Experimental Location

The study was conducted in the Plant Pathology Laboratory at the Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jashore. The lentil variety used for the experiment was BARI Masur-6.

Preservation Containers

Six types of storage containers were utilized in the experiment:

1. Cotton cloth bag (C1)
2. Tin container (C2)
3. Earthen pot (C3)
4. Plastic container (C4)
5. Polythene bag (C5)
6. Gunny bag (C6)

Plant Extracts

Four plant extracts were tested for their efficacy:

1. Betel leaf (*Piper betel*) (T1)
2. Neem leaf (*Azadirachta indica*) (T2)
3. Garlic (*Allium sativum*) (T3)
4. Mahogany leaf (*Swietenia mahagoni*) (T4)

Preparation of Plant Extracts for Seed Storage

Leaves of *Piper betel*, *Azadirachta indica*, *Swietenia mahagoni*, and cloves of *Allium sativum* were cleaned, cut into small pieces, and blended in distilled water to prepare a 1% (w/v) solution. Each plant material (10 g) was blended with 1 liter of distilled water. These solutions were applied to the seeds using a hand sprayer. The seeds were then air-dried before storage, following the methodology of Tohmi et al. (2012).

Calculation of Vigor Index

Seedling vigor and germination percentages were recorded at 2, 4, and 6 months of storage. At the end of 6 months, a blotter test was conducted to assess germination and fungal infection rates. Seedling vigor was calculated using the formula:

VI = Dry weight of 10 seedlings X germination percentage (Kashem et al. 2005).

The experiment followed a Complete Randomized Design (CRD) with three replications. The treatment combinations were as follows: C1T1, C1T2, C1T3, C1T4, C2T1, C2T2, C2T3, C2T4, C3T1, C3T2, C3T3,

C3T4, C4T1, C4T2, C4T3, C4T4, C5T1, C5T2, C5T3, C5T4, C6T1, C6T2, C6T3, and C6T4. Germination percentage, fungal association, and vigor index were statistically analyzed using ANOVA in SPSS 15, with means compared using Duncan's New Multiple Range Test (DMRT).

Pre-Sowing Seed Treatments

The following treatments were applied to control seed-borne diseases in lentils:

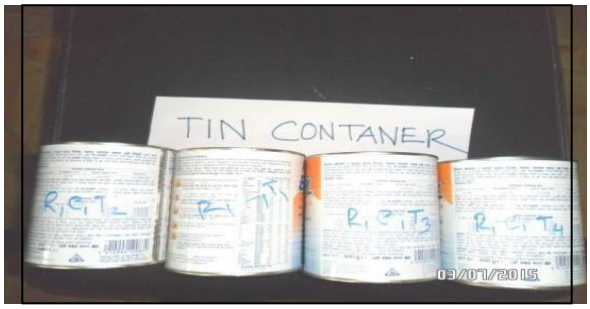
1. Garlic (5% w/v aqueous solution) (Tohami et al., 2002)
2. Datura (5% w/v aqueous solution) (Tohami et al., 2002)
3. Mahogany leaf extract (5% w/v aqueous solution) (Tohami et al., 2002)
4. Mahogany seed extract (5% w/v aqueous solution) (Tohami et al., 2002)
5. Fern leaf extract (5% w/v aqueous solution) (Tohami et al., 2002)
6. Ash coating (10 g/kg seed) (Meena, 2012)
7. Fresh cow dung coating (5 g/kg seed) (Meena, 2012)
8. Cow urine (5% v/v aqueous solution) (Meena, 2012)
9. Provax-200 (2 g/kg seed)
10. Control (untreated)

Preparation of Plant Extracts for Pre-Sowing Seed Treatment

Plant parts were cleaned, chopped, and blended with distilled water at a 1:1 ratio (100 g of plant material in 100 ml of water). The extracts were filtered through cheesecloth and stored at 4±1°C. Seeds were soaked in these extracts for 25 minutes, then air-dried. For ash and cow dung treatments, seeds were coated in a conical flask with the respective materials. Provax-200 was applied at 2 g/kg seed, and seeds were air-dried under cool conditions (Ahmed, 2011).

Blotter Test

Germination and fungal association were assessed using the blotter test method (ISTA, 2001). Four hundred seeds were randomly selected and placed on three-layered, sterilized, water-moistened blotter paper in sterilized glass petri dishes (9x12 cm), with 25 seeds per dish. Petri dishes were sterilized at 120°C for 12 hours before plating. The dishes were incubated at room temperature under a 12-hour light/dark cycle for seven days. The pre-sowing seed treatment experiment followed a CRD with four replications. Germination and seed infection percentages were recorded and analyzed using standard error and standard deviation formulas in MS Excel.



C_1

C_2

C_3

C_4

C_5 C_6

Figure 1. Different seed storing containers C1= Cloth bag, C2= Tin container, C3=Earthen pot, C4= Plastic container, C5= Polythene bag and C6= Gunny bag

T_1 T_2

T_3 T_4

Figure 2. Photograph of different botanicals T_1= Piper betel, T_2=Neem leaf T_3=Garlic and T_4= Mehogani leaf

Six containers and four plant extracts were used in this experiment. Germination percentage and vigor index after 2, 4 and 6 months showed significant difference amongthe treatments.

RESULTS

Germination percentage and Vigor Index (VI) at 2 months after storing

After 2 months of seed storage, a polythene bag containing neem leaf extract (C5T2) had the highest germination percentage (96.00%), followed by a polythene bag containing piper betel extract (C5T1) (92.00%). The results were statistically equivalent for both the polythene bag with mahogany extract (C5T4) (92.00%) and the polythene bag with garlic clove extract (C5T3) (91.00%). We reported the germination rate of seeds treated with garlic clove extract (C6T3) and stored in a gunny bag for 2 months as 80.67%, the lowest among all treatments. The polythene bag with neem leaf extract (C5T2) had the greatest vigor index (VI) at 105.60, followed by the polythene bag with garlic clove extract (C5T3) at 90.09. Table 1 shows that the application of mahogany leaf extract to gunny bags (C6T4) resulted in the lowest VI value of 59.28.

Germination percentage and Vigor Index (VI) at 4 months after storing

After 4 months, storing the seeds in a polythene bag with neem leaf extract (C5T2) resulted in the highest germination percentage (94.00%). A polythene bag containing mahogany leaf extract (C5T4) followed, exhibiting a germination percentage of 90.33%. The polythene bag with piper betel extract (C5T1) had a germination percentage of 90.00%, and the polythene bag with garlic clove extract (C5T3) had a germination percentage of 89.00%. Treating the seeds with garlic clove extract (C6T3) and storing them in gunny bags resulted in the lowest germination rate (78.67%). The polythene bag with neem leaf extract (C5T2) had the greatest vigor rating, measuring 102.44. The polythene bag with garlic clove extract (C5T3) followed with a vigor level of 88.11. The therapy that resulted in the lowest VI was the combination of gunny bag with neem leaf extract (C6T2), with a recorded value of 57.27 (Table 1).

Germination percentage, VI and seed infection at 6 months after storing

The germination percentage was highest (94.33%) after 6 months in the polythene bag containing neem leaf extract (C5T2), followed by the polythene bag containing garlic clove extract.We measured the efficiency of C5T3 at 90.33%, and the efficiency of the polythene bag containing mahogany leaf extract (C5T4) at 91.00%. Treating seeds with garlic clove extract (C6T4) and storing them in a gunny bag resulted in the lowest germination rate (64.00%). The polythene bag treated with neem leaf extract (C5T2) had the greatest vigor index, measuring 99.40. Garlic clove extract treated the gunny bag next. The gunny bag treated with mahogany leaf extract (C6T4) had the lowest VI value, 45.77. The highest rate of seed infection, at 39.17%, was observed in C1T2 (a cotton fabric bag treated with neem leaf extract), which was comparable to the infection rate of 38.23% in C1T4. C5T4, which used polythene bags containing mahogany leaf extract, had the lowest incidence of seed infection (5.87%). The seed infection rates in the C5T2 and C5T3 treatments were 7.37% and 7.44%, respectively, which were statistically indistinguishable from the infection rate in the C5T4 treatment. We also observed seed infection on the blotter after 6 months. C5T4 (5.87%) had the lowest seed infection rate, storing seeds in a polythene bag containing mahogany leaf extract. C5T2 (7.37%) and C5T3 (7.44%) followed, storing seeds in a polythene bag containing neem leaf extract and a polythene bag containing garlic clove extract, respectively. The seed infection rate was highest in C1T2, with a prevalence of 39.17%, followed by C1T4 with 38.23%, and C1T3 with 34.33%. The study found that the seed infection rate was the lowest when using polythene bags, as shown in Table 1.

Effect of pre-sowing seed treatment on fungal association

Various compounds employed in pre-sowing seed treatment exhibited varying responses against seed-borne fungi. The occurrence of Fusarium oxysporum varied from 0.50% to 6.67%. This fungus observed the highest incidence of seed infection in seeds treated with fresh cow dung and the control group (6.67%), followed by both mahogany leaf and seed extract (5.42%) and ash (5.41%). The lowest seed infection rate (0.50%) was found in seeds treated with Provax-200, followed by garlic clove extract (1.67%) in the case of F. oxysporum. The incidence of Alternaria tennuis infection was highest (5.75%) in the control group, followed by the seed coated with ash (4.25%) and fresh cow dung (3.67%). The seed treated with Provax-200 had the lowest infection rate (0.33%), followed by the garlic clove extract (1.08%). The prevalence of Stemphylium botryosum was highest in the control group (6.17%), followed by the groups treated with fern leaf extract (3.67%), mahogany leaf extract, and fresh cow dung (3.50%). The seed treated with Provax-200 had the lowest infection rate (0.17%), followed by the garlic clove extract (0.58%). Curvularia luanata caused the highest incidence of seed infection in the control group (5.25%), followed by the fern leaf extract group (2.33%) and the mahogany leaf extract group (2.25%). The seed treated with Provax-200 (0.50%) had the lowest incidence of fungal infection, followed by the garlic clove extract and the seed coated with ash (0.92%). The control group displayed the highest occurrence of Penicillium cladosporium association with seed (9.92%), followed by both mahogany seed extract and fern leaf extract (7.50%), and ash coating (6.42%). The fungus was least prevalent in the seed treated with Provax-200 (1.08%) and somewhat more prevalent in the seed treated with garlic clove extract (1.75%). Aspergillus niger caused the most significant seed infection in the seed treated with cow urine (9.33%), followed by fresh cow dung (9.00%) and mahogany seed extract (8.92%). The seed treated with Provax-200 had the lowest incidence of infection (2.83%), followed by the garlic clove extract treatment (3.65%). The control group had the highest prevalence of Aspergillus flavus (10.25%), followed by groups T7, T3, and T6. A. flavus caused the lowest seed infection in the Provax-200, with a rate of 2.92%, followed by garlic clove extract at 1.67%. The control group had the highest incidence of seed infection by Aspergillus ochraceous at 6.25%, followed by the mahogany leaf extract group at 4.50% and the mahogany seed extract group at 4.42%. The seed treated with Provax-200 had the lowest infection rate by this fungus, at 0.17%, followed by the garlic clove extract at 2.92%. The control group had the highest rate of Aspergillus parasiticus seed infection, with a prevalence of 3.50%, which was comparable to other groups. The sequence begins with the application of mahogany seed extract, followed by cow urine (3.41%). The seed treated with Provax-200 (0.08%) had the lowest incidence of infection by A. parasiticus, followed by the garlic clove extract treatment (1.50%). Both the control group and the fern leaf extract group showed the highest association of Aspergillus candidus (2.92%), followed by the datura leaf extract and ash group (2.42%). The seed treated with Provax-200 had the lowest association rate of 0.58%, whereas the garlic clove extract had a slightly higher association rate of 1.00%.. We computed the percentage increase in seed infection compared to the control. The

seed infection showed the greatest enhancement in Provax-200 (87.81%), followed by garlic clove extract (74.70%) and fresh cow dung-coated seed (60.64%). The seed infection showed the least improvement in mahogany seed extract (28.40%), followed by mahogany leaf extract (28.82%), as indicated in Table 2.

Table1. Effect of different container and plant extract on seed germination, seedling vigor and percent seed infection

Treatments	% Germination 2 months	% Germination 4 months	% Germination 6 months	VI at 2 months	VI at 4 months	VI at 6 months	% seed infectionat 6 months
C1T1	82.33ij	80.00jk	65.33h	65.87h	66.77hij	50.30hi	34.41b
C1T2	83.33hij	81.33jk	67.00gh	73.33e	71.57e-h	59.30g	39.17a
C1T3	84.00g-j	80.33jk	68.33gh	66.36gh	63.72ijk	54.05h	34.33b
C1T4	82.67ij	80.67jk	65.33h	64.77hi	62.92ijk	51.81h	38.23a
C2T1	87.00d-h	85.00e-i	71.33fg	78.30d	76.22c-f	63.90f	32.04bc
C2T2	88.00c-f	85.67d-h	74.67ef	78.32d	76.26c-f	65.90f	26.50efg
C2T3	87.33c-g	85.00e-i	73.67ef	70.74ef	68.85ghi	58.65g	26.05e-h
C2T4	87.00d-h	84.67f-i	77.33e	71.05ef	68.06ghi	63.99f	27.13def
C3T1	85.33e-i	83.33g-j	77.67e	68.28fgh	66.66hij	62.70fg	28.19de
C3T2	85.33e-i	83.33g-j	68.00gh	67.41fgh	63.18ijk	54.02h	24.18fgh
C3T3	84.33f-j	82.33h-k	66.33h	60.72j	59.72jk	50.28hi	23.60gh
C3T4	84.00g-j	82.33h-k	75.67ef	59.64j	64.04ijk	54.30h	22.83h
C4T1	90.67bcd	88.67b-e	86.67bcd	77.97d	78.03cde	72.35de	9.78jk
C4T2	90.33bcd	88.33b-f	85.33cd	78.90d	78.90cd	76.44cd	12.41j
C4T3	89.67bcd	88.00b-f	87.67bcd	80.10d	74.83c-g	77.52c	10.14jk
C4T4	88.33b-e	86.33c-g	84.00d	69.78efg	73.50d-h	71.54e	12.41j
C5T1	92.00b	90.00bc	89.00bc	83.72c	81.06c	87.28b	7.65kl
C5T2	96.00a	94.00a	94.33a	105.60a	102.44a	99.40a	7.37kl
C5T3	91.00bc	89.00bcd	91.00ab	90.09b	88.11b	83.71b	7.44kl
C5T4	92.00b	90.33b	91.00ab	70.84ef	69.56f-i	70.84e	5.87l
C6T1	81.67ij	79.67jk	66.00h	61.25ij	59.95jk	50.58h	30.42cd
C6T2	82.67ij	80.67jk	73.67ef	58.69j	57.27k	50.13hi	18.60i
C6T3	80.67j	78.67k	66.67h	62.13ij	60.57jk	51.23h	27.77de
C6T4	83.33ij	80.33jk	64.00h	59.28j	57.48k	45.77i	27.85de
CV (%)	2.32	2.34	2.26	2.86	5.44	4.10	8.37
F-test	**	*	**	*	*	*	**

N.B. VI= Vigor index, C1=Cloth bag, C2=Tin container, C3=Earthen pot, C4=Plastic container, C5=Polythene bag and C6=Gunny Bag; T1=Piper betel, T2=Neem leaf, T3= Garlic T4=Mahogany leaf. Mean(s) followed by common letter(s) do not differ significantly at 0.05 level. *=significant at 0.05 level, **=significant at 0.01 level.

Germination percentage influenced by pre-sowing seed treatment

The germination percentages were recorded and found to be highest in the seed treated with Provax-200 (93%), followed by garlic clove extract (81.42%) and datura leaf extract (79.17%). The seed treated with fresh cow dung exhibited the lowest germination percentage, which was 56.50% (Figure 3).

Table 2. Fungal infection in lentil seed treated with biological agents and fungicide

Treatmnts	% fungal infection											
	Fusarium oxysporum	*Alternaria tennuis*	*Stemphylium Botryosum*	*Curvularia Lunata*	*Penicillium cladosporium*	*Aspergillu sNiger*	*A. flavus*	*A. ochraceous*	*A. paraciticus*	*A. candidus*	Total	% Improve-ment
T1	1.67	1.08	0.58	0.92	1.75	3.65	2.92	0.83	1.50	1.00	15.90	74.70
T2	4.33	3.33	2.83	1.83	5.83	6.50	5.75	3.25	2.08	2.42	38.15	39.30
T3	5.42	3.42	3.50	2.25	6.33	8.75	6.42	4.50	2.48	1.67	44.74	28.82
T4	5.42	3.58	3.33	2.08	7.50	8.92	4.17	4.42	3.50	2.08	45.00	28.40
T5	3.83	2.58	3.67	2.33	7.50	8.08	5.42	2.67	3.08	2.92	42.08	33.04
T6	5.41	4.25	3.17	0.92	6.42	8.08	6.25	4.00	2.67	2.42	43.59	30.64
T7	6.67	3.67	3.50	1.50	5.50	9.00	6.58	2.83	2.50	1.92	43.67	60.64
T8	4.42	2.92	3.00	1.50	6.17	9.33	5.33	2.83	3.41	2.17	41.08	34.64
T9	0.50	0.33	0.17	0.50	1.08	2.83	1.67	0.17	0.08	0.58	7.91	87.41
T10	6.67	5.75	6.17	5.25	9.92	6.17	10.25	6.25	3.50	2.92	62.85	-
Mean±SE	4.43±0.78	3.09±0.64	2.99±0.67	1.91±0.25	5.80±0.84	7.13±0.77	5.48±0.72	3.18±0.71	2.48±0.45	2.01±0.45	-	-

N.B. T1=Garlic clove extract, T2=Datura leaf extract, T3= Mahogany leaf extract, T4= Mahogany seed extract, T5= Fern leaf extract, T6= Coated with ash,T7= Coated with fresh cow dung, T8= Cow urine, T9= Provax-200 and T10= Control (untreated)

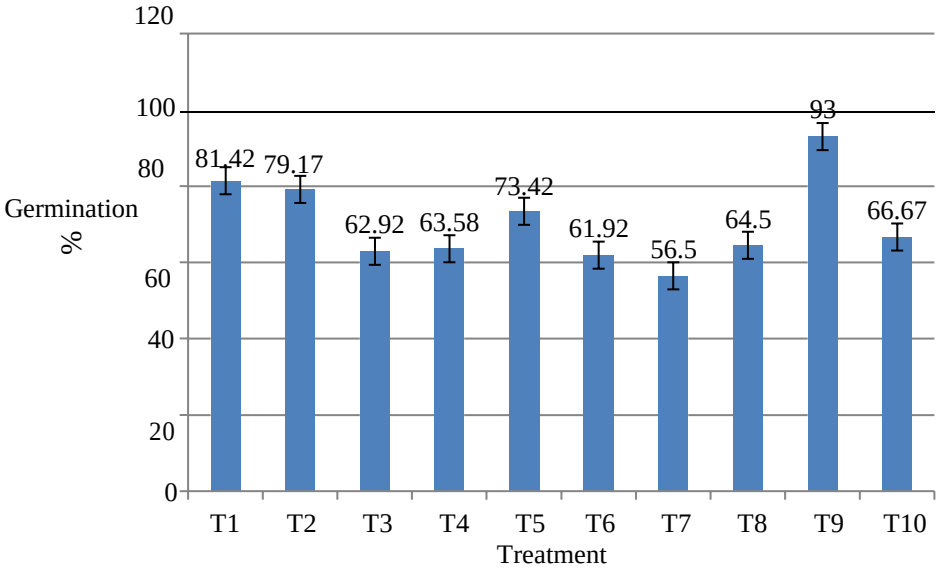


Figure 3. Effect of seed treatment by biological agents and fungicide on seed germination

DISCUSSION

It was clearly shown that lentil seeds stored in a polythene bag with neem leaf extract did better than other treatments when it came to germination, vigor index, and seed infection (Table 1). We found that the durability of lentil seeds significantly diminished as the storage time increased. Sadhu and Kar (2009) found comparable results when using neem extract to treat blackgram seeds. Additionally, researchers found that lentil seeds retain their vitality more effectively in a polythene bag than in other types of bags or containers. Kashem et al. (2005) observed in their study that storing lentil seeds in a polythene bag improved germination, plant growth, and seedling vigor. However, Prashant et al. (2007) discovered that piper betel is more efficient in preserving the germination and vigor of rice seeds. Both this study and earlier related studies demonstrate that storing seeds with the appropriate moisture content in an airtight container results in improved health. A container that lacks total air-tightness fails to prevent air from coming into contact with the seed. This results in the absorption of moisture from the air, which stimulates the seed's physiological processes and allows seed-borne fungus to cause the seed's health to decline over time.

Polythene bags prevent external air from entering the seed, whereas cloth and gunny bags do not. Presumably, external air manages to infiltrate the plastic and tin containers. The results clearly demonstrate that the seed-treating fungicide Provax-200 had a significant impact on lowering the presence of fungus by 87.41% and boosting the germination percentage of lentil seeds by 39.49% (Table 2 and Figure 3). Uddin's (2009) study found that Vitavax-200, formerly known as Provex-200, was the most effective in reducing seed-borne infections in lentils. Afzal et al. (1999) also found that applying Vitavax-200 to the seeds decreased the occurrence of foot and root rot in lentil plants. Mortuza et al. (2002) found that the use of Captan fungicide effectively suppressed Fusarium wilt in chickpeas, as well as the fungi Aspergillus niger and A. flavus. Garlic clove extract, datura leaf extract, and fern leaf extract decreased fungal association by 74.78%, 39.30%, and 33.04%, respectively, while increasing seed germination by 22.30%, 18.89%, and 10.15%, respectively. Hermansen et al. (1999) claimed that using biological agents to treat seeds had no impact on carrots. However, our study's findings contradict this claim and align with Alice and Rao's (1994) research. They found that using garlic clove extract effectively controlled seed-borne

diseases in rice caused by Drechslera oryzae. This investigation corroborates the findings of Khan and Kumar (1992) that garlic clove extract, ghagra, vatpata, and bishkatali leaf extract effectively decreased the occurrence of fungus in wheat seeds. In their study, Yasmeen and Saxena (1992) discovered that plant extracts can effectively inhibit seed-borne fungi. The majority of researchers have concluded that fungicides are the most efficacious means of controlling seed-borne fungus, surpassing other agents (Mortuza and Bhuiya 1988). Fungicides are potent chemical substances that possess the ability to effectively eliminate and inhibit fungus growth. Additionally, their residual properties provide protection to germinating seeds by preventing the transmission of pathogens present in the soil. Fungal infections were lowered by 28.82%, 28.40%, 30.64%, 60.64%, and 34.64% when mahogany leaf extract (T3), mahogany seed extract (T4), ash-coated seeds (T6), fresh cow dung-coated seeds (T7), and cow urine (T8) were used. However, the study also revealed a reduction in germination rates compared to the control group, with reductions of 5.62%, 4.63%, 7.12%, 15.25%, and 3.25%, respectively. The effects on germination exhibit inconsistency. These biological substances may have a detrimental effect on the lentil embryo, leading to a decrease in the percentage of germination. It was found that adding undecomposed cow dung to the soil cut down on fungal infections by 60.64% and germination by 15.25% compared to the control group, which had the biggest drop. According to Sherfudeen et al. (2015), undecomposed cow manure has the ability to kill bacteria and germs.

CONCLUSION

This study explored effective methods for preserving lentil seeds using various storage containers and botanical treatments to enhance germination, vigor, and reduce seed-borne fungal infections. Lentil seeds stored in polythene bags with neem leaf extract showed the highest germination rates, vigor indices, and lowest fungal infections over six months. Provax-200 fungicide reduced fungal infections by 87.41% and increased germination by 39.49%, while garlic clove extract also significantly improved seed health. These findings highlight the effectiveness of polythene bags with neem extract and fungicides like Provax-200 for seed preservation. Future research should examine the long-term impacts and sustainability of these treatments. Our study provides valuable guidelines for improving lentil seed preservation and agricultural productivity.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The authors have no conflict of interest to declare.

Author contribution

All the authors read and approved the final manuscript. All the authors verify that the text, figures, and tables are original and that they have not been published before.

Jahan Al Mahmud: Principal Investigator for the research, responsible for conceptualization, methodology, and overall project administration.

Mahtalat Ahmed: Co-supervisor, provided guidance on research design, data analysis, and interpretation.

Sanjoy Kumar Adhikary: Supervisor, provided oversight and critical revisions to ensure the research met academic and publication standards.

Md. Mamun Hossain: Contributed to drafting the manuscript, editing, and assisted in the final preparation for journal submission.

Md. Mahadi Morshed: Contributed to manuscript drafting, editing, and integrating revisions from reviewers, and incorporating reviewers feedback. Supported the publication process in the journal.

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