International Journal of Advanced Biochemistry Research 2025; 9(8): 76-80

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(8): 76-80
www.biochemjournal.com
Received: 01-05-2025
Accepted: 06-06-2025

Shubhangi Ahirrao
M.Tech Student, Department of Agricultural Process Engineering, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

PH Bakane
Professor and Head, Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

VD Mohod
Assistant Entomologist, AICRP on Post harvest Engineering and Technology, Post graduate Institute, Dr. PDKV, Akola, Maharashtra, India

RD Bisen
Senior Research Assistant, AICRP on PHET, Dr. PDKV, Akola, Maharashtra, India

SR Kalbande
Professor and Dean, Faculty of Agricultural Engineering and Technology, Dr. PDKV, Akola, Maharashtra, India

Corresponding Author:
Shubhangi Ahirrao
M.Tech Student, Department of Agricultural Process Engineering, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Optimizing UV-C irradiation for reducing storage losses in pigeon pea grains by pulse beetle (*Callosobruchus maculatus*)

Shubhangi Ahirrao, PH Bakane, VD Mohod, RD Bisen and SR Kalbande

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8b.5078

Abstract

Post-harvest losses in pigeon pea (*Cajanus cajan*) due to insect infestation significantly impact grain quality and shelf life. This study aimed to evaluate the effectiveness of ultraviolet (UV-C) irradiation and optimization of machine parameter and processing time to minimize post-harvest losses. The experiment was laid in Completely Randomized Design with 13 treatments, replicated twice. A custom-designed UV treatment machine was developed to expose grains to UV-C light (254 nm) at varying feed rates (200, 350, and 500 kg/h) and exposure durations (15, 30, 45, and 60 minutes). Treated and untreated (control) grain samples were stored under ambient conditions for six months, and key storage parameters such as moisture content, percent grain damage, and weight loss due to insect infestation were measured at an 15-day interval up 180 DAS period .

The results demonstrated that UV treatment significantly reduced storage losses compared to untreated samples. Among the treatments, grains treated at lower feed rates (200 Kg/h) and longer exposure durations (60 min) showed the least insect damage (8.7%) and weight loss (0.9%) after 180 days of storage. The insect damage percentage and weight loss percentage in untreated sample was found high as 46% and 9.3% respectively. The UV treated grains were maintaining a lower moisture level as compared to untreated grains throughout storage period resulting moisture reduction due to UV Irradiation.

UV-C irradiation was found to be an effective method for enhancing the shelf life and maintaining the post-harvest quality of pigeon pea grains, offering a promising alternative to chemical storage treatments.

Keywords: UV-C irradiation, pigeon pea, insect damage, post-harvest loss, grain quality, storage

Introduction

Pigeon pea is the main source of protein for more than billions of people in regions such as Asia, Africa, South America, Central America, and the Caribbean. Also, it serves as an essential cash crop to support the livelihoods of millions of resource-poor farmers in these areas (Susmitha 2022) [15]. The nutritional composition of pigeon pea is similar to that of other legumes. It has a low-fat content and high protein. As numerous findings indicate, pigeon pea contains 20%-22% protein, 65% carbohydrate, 3.8% ash, and 1.2% fat (Sarkar *et al.* 2020) [10]. Pigeon peas have two to three times more protein than cereals specifically rich in lysine (Jawalekar *et al.* 2020) [5]. It is a good source of dietary fiber, vitamins, and minerals (Talari and Shakappa, 2018) [16].

The country's total area coverage and production of tur has been about 46 Lakh ha and 40 Lakh tone respectively. Maharashtra ranked first (>12 Lha) contributes 27% in area and 29% in production, whereas, Karnataka has contributed 31 percent of area and 26 percent of total production. (DPD annual report 2022-23).

However, the susceptibility of pigeon pea to infestation by the pulse beetle, scientifically referred to as *Callosobruchus maculatus*, presents a significant challenge, demanding an immediate need for comprehensive understanding and effective mitigation strategies. The pulse beetle, a formidable adversary to legume crops, has emerged as a substantial threat, resulting in significant protein content losses within pigeon pea grains. What initiates as an infestation by *C. maculatus* in the field extends into storage conditions (Karthik *et al.*, 2023)

[6]. A temporal progression highlights that three to six months subsequent to the initial infestation, up to 90% of the beans become vulnerable to infestation, coupled with weight losses ranging from 30% to 60% (Singh 2023) [14].

The utilization of dust and fumigants is successful in managing bruchids but is inefficient at the farm level due to non-sealed rural storage systems. The application of pesticides in food grains stored for consumption purposes is harmful. Inappropriate application of chemicals impacts the ecosystem and disturbs the food chain contributing to bio magnifications. A further limiting factor under consideration is the establishment of resistance by preserved grain pests against certain insecticides. A few strains of *Tribolium castaneum* and pulse beetle had already developed resistance against malathion (Mishra, 2021) [7].

Ultraviolet (UV) radiation, known for its germicidal properties, has been utilized in insect management (Sheeja and Jones, 2015) [13]. It serves as a surface disinfectant for insect eggs and as an attractant in physiological and embryological studies involving beetles (Sedaghat *et al.*, 2014) [11]. The use of UV Irradiation is one of the potential agents for controlling insect pests in stored grains and their products (Faruki *et al.*, 2007) [3]. Irradiation becomes an established technique for controlling stored product insects because of residue free advantages over chemical fumigation (Sedehi A, 2014) [12]. Among non-thermal disinfestation methods for stored food grains, UV irradiation stands out as clean, rapid, and cost-effective, with minimal residual impact on the grains. Therefore, it holds significant promise as a method for insect control. In light of this, the present study aims to evaluate the effect of UV irradiation on stored pigeon pea grains to reduce storage losses caused by insect infestation.

Materials and Methods

The present experiment and investigations on effect of UV irradiation on pigeon pea were carried out at AICRP on Post-Harvest Engineering and Technology, and Department of Agricultural Process Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during year 2024-2025.

UV Treatment Machine

A UV treatment machine was fabricated using a mild steel frame (35 mm × 35 mm × 3 mm). It consisted of a feeding hopper, U-shaped trough, screw conveyor, and electric motor. The feeding hopper, conical in shape, was equipped with a stirring mechanism to ensure uniform grain flow. The U-shaped trough housed a helical screw conveyor made of mild steel (shaft diameter: 33 mm, blade diameter: 11 cm, pitch: 8 cm, length: 2.64 m). The conveyor was operated by a 1 HP electric motor via a chain and pulley system connected to a variable frequency drive.

Nine UV-C fluorescent tube lights (Anchor VIVA, Panasonic) of 15 W power and 254 nm wavelength were installed at 10 cm above the trough to ensure uniform irradiation. The system was enclosed with a resin sheet to prevent UV exposure to operators, who were provided with protective gloves and aprons, goggles during operation.

Sample Preparation and Treatment

Latest harvested pigeon pea grains of variety PKV Tara (15 kg per treatment) were cleaned using a screen and subjected to UV irradiation at three feed rates (200, 350, and 500 kg/h) and four exposure durations (15, 30, 45, and 60 minutes), resulting in 12 treatment combinations along with an untreated control (T_{13}). After treatment, samples were packed in polypropylene bags, sealed, labeled, and stored under ambient conditions for a period of six months.

Observations during Storage

1. Moisture Content (%): Samples were analyzed at 30-day intervals throughout the storage period. Moisture content (%) was determined by oven drying at 105 ± 1 °C for 24 hours.

$$\text{Moisture content (\%)} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100$$

2. Percent Damage

The representative sample of each treatment, total number of grains and damaged grains was counted and percent damage was calculated by following formula (Nakambam, 2022) [8]

$$\text{Percent damage (\%)} = \frac{\text{Total number of damage grains}}{\text{Total numbers of grains}} \times 100$$

3. Weight loss due to insect infestation

Weight loss (%) in stored pulses was determined using representative sample of approximately 100g. The insect-infested grains separated from the sample, then the number and weight both insect-damaged and undamaged grains was recorded. The weight loss due to insect infestation was calculated using the formula provided by Manual of ICAR (Storage management of major legumes):

$$\text{Weight Loss} = \frac{M_u N_d - M_d N_u}{M_u N_u + M_d N_d} \times 100$$

where,
M_u = weight of undamaged grains,
M_d = weight of damaged grains,
N_u = number of undamaged grains,
N_d = number of damaged grains.

Results and Discussion

Effect of UV Irradiation on Moisture Content of Pigeon Pea during Storage

The moisture content of pigeon pea seeds was recorded at 15-day intervals up to 180 days of storage. The observations and statistical analysis by ANOVA is shown in Table 1

Moisture content indicated a decreasing trend over the storage period across all treatments. Initially, moisture content ranged between10.3% to 13.1%. After 180 days, it dropped to between 9.85% (T_4) and 11.51% (T_{13}-Control). The untreated grains were maintained higher moisture level as compared to UV treated grains throughout storage period. Mean minimum moisture level was observed in treatment T_4 (10.92%) (60 min, 200 kg/h) and T_3 (11.01%) (45 min, 200 kg/h), followed by treatment T_2 (30 min, 200 kg/h) and T_8 (60 min, 350 kg/h) and these treatments were at par with each other. However, T_{12} (60 min, 500 kg/h) recorded higher moisture 12.39% in UV treatments, resulting that longer exposure at lower feed rates enhanced drying effects and moisture reduction.

Table 1: Effect of UV irradiation on moisture content over storage period

TR	Treatment Details	Moisture Content% Days After Storage												Mean
		15	30	45	60	75	90	105	120	135	150	165	180	
T_1	UV light exposure at 200 kg/h feed rate for 15 min	11.8	12.40	12.24	12.29	12.15	11.79	11.75	12.03	11.70	11.90	10.37	10.51	11.680
T_2	UV light exposure at 200 kg/h feed rate for 30 min	11.0	11.89	11.75	11.60	11.60	11.00	11.51	11.66	11.36	11.40	10.09	10.13	11.225
T_3	UV light exposure at 200 kg/h feed rate for 45 min	10.6	11.12	11.75	11.30	11.50	10.85	11.45	11.49	11.20	11.17	9.84	10.02	11.015
T_4	UV light exposure at 200 kg/h feed rate for 60 min	10.3	11.21	11.50	11.15	11.25	10.70	11.20	11.40	11.00	11.10	9.32	9.85	10.920
T_5	UV light exposure at 350 kg/h feed rate for 15 min	12.0	12.45	12.35	12.36	12.19	11.93	11.97	12.13	11.85	12.10	10.82	10.67	11.835
T_6	UV light exposure at 350 kg/h feed rate for 30 min	11.8	12.34	12.15	12.17	12.00	11.59	11.73	11.92	11.56	11.84	10.34	10.33	11.630
T_7	UV light exposure at 350 kg/h feed rate for 45 min	11.7	12.14	12.05	12.12	11.85	11.50	11.72	11.84	11.52	11.55	10.31	10.23	11.510
T_8	UV light exposure at 350 kg/h feed rate for 60 min	11.3	11.95	11.85	11.92	11.75	11.32	11.53	11.77	11.47	11.43	10.13	10.15	11.335
T_9	UV light exposure at 500 kg/h feed rate for 15 min	12.1	12.54	12.52	12.55	12.30	12.20	12.16	12.34	12.00	12.35	10.99	11.09	12.030
T_{10}	UV light exposure at 500 kg/h feed rate for 30 min	12.0	12.50	12.45	12.36	11.84	12.14	12.06	12.21	11.95	12.23	10.92	10.70	11.805
T_{11}	UV light exposure at 500 kg/h feed rate for 45 min	12.3	12.75	12.60	12.82	12.55	12.36	12.30	12.67	12.05	12.37	11.18	11.15	12.180
T_{12}	UV light exposure at 500 kg/h feed rate for 60 min	12.7	12.85	12.70	12.90	12.79	12.76	12.37	12.79	12.25	12.47	10.82	11.25	12.175
T_{13}	Untreated Control	13.1	13.00	12.74	13.07	12.43	13.03	12.92	12.85	12.67	13.15	11.76	11.51	12.545
	SE (m±)	0.23	0.2	0.08	0.35	0.21	0.12	0.12	0.25	0.13	0.26	0.35	0.31	0.050
	CD at 5%	0.70	0.6	0.26	1.07	0.66	0.37	0.32	0.78	0.39	0.79	1.09	0.95	0.154
	CV	2.74	2.23	0.96	4.01	2.49	1.42	1.24	2.96	1.50	3.02	4.73	4.13	0.60

Effect of UV irradiation on percent damage by pulse beetle during storage

The data on insect damage percentage in pigeon pea during storage as influenced by UV irradiation treatments were statistically analyzed using a Completely Randomized Design (CRD).

From the Table 2 exhibited that the grain treated under UV treatment machine under different feeding rate and exposure period, as per treatments found that all the treatments were statistically significant over untreated control. In all treatments, insect damage increased gradually with increasing storage duration. However, the extent of damage varied significantly based on UV exposure time and feed rate.

The mean percent damage during storage in the range of 1.94 to 11.18 percent. Among the treatments, T_4 (200 kg/h feed rate for 60 minutes) showed the lowest insect damage (1.94%), which was statistically at par with T_3 (2.80%) and T_2 (3.41%) and T_8 (3.78%). These treatments consistently showed better protection against infestation throughout the storage period.

Moderate control was observed in treatments T_7 (350 kg/h, 45 min) and T_6 (350 kg/h, 30 min), with mean damage percentages of 4.21% and 4.63%, respectively. These were significantly better than higher feed rate treatments but less effective than the 200 kg/h feed rate group. In contrast, treatments with a 500 kg/h feed rate (T_9 to T_{12}) exhibited relatively higher damage levels, ranging from 9.44% and 11.18. Despite longer exposure durations, the high feed rate appears to have reduced the effective UV contact time per unit grain, leading to reduced efficacy. This is because at higher feed rates the volume of grain in trough increases and UV exposure light does not reach to every grain. The untreated control (T_{13}) recorded the highest insect damage, reaching 46.01% at 180 DAS, indicating heavy infestation under ambient storage conditions. In contrast, all UV-irradiated treatments recorded significantly lower damage percentages, confirming the positive effect of UV irradiation on pest control during storage. The result was in conformity with Azizoglu *et al.* that the enhance mortality rate of insect increased with increasing exposure time period of UV radiation.

Effect of UV irradiation on weight loss by pulse beetle during storage

From the table 3, it was found that all UV-treated samples had lower weight loss compared to the untreated control**.** The control sample (T_{13}) showed the highest weight loss after 180 days (9.36%), which means more grains got damaged or lost weight during storage.

Among the UV treatments, T_4 (200 kg/h for 60 min) had the lowest mean weight loss (0.16%), showing that longer UV exposure at a lower feed rate helped in better preserving the quality of pigeon pea and these treatments were at par with treatment T_3 (200 Kg/h for 45 min) and T_2 (200kg/h for 30 min) had percent weight loss of 0.24% and 0.31% respectively. Similarly treatment T_8 (350 Kg/h, 60 min) also showed low weight loss (0.39%) and this treatment was at par with treatment T_7 (350 kg/h, 45 min), T_6 (350 kg/ h 30 min) respectively.

However, treatments with higher feed rates like T_{12} (500 kg/h for 60 min) and T_{11} (500 kg/h for 45 min) observed relatively higher weight loss 1.34% and 1.12% respectively. This means that increased feed rates lead to greater grain depth in the trough that higher, UV light not reach all grains equally, reducing its effectiveness.

Table 2: Effect of UV irradiation on damage percent by pulse beetle during storage

TR	Treatment Details	Insect Damage Percent Days after storage												Mean
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	150 DAS	165 DAS	180 DAS	
T_1	UV light exposure at 200 kg/h feed rate for 15 min	0.42 (1.19)	0.42 (1.19)	0.49 (1.22)	0.85 (1.35)	1.49 (1.58)	2.03 (1.74)	1.76 (1.66)	2.29 (1.81)	3.47 (2.11)	5.17 (2.48)	20.63 (26.8)	21.37 (27.45)	5.03 (5.88)
T_2	UV light exposure at 200 kg/h feed rate for 30 min	0.05 (1.02)	0.26 (1.12)	0.37 (1.17)	0.59 (1.26)	1.24 (1.50)	1.25 (1.5)	1.37 (1.54)	1.12 (1.46)	1.99 (1.78)	2.47 (1.86)	14.94 (22.42)	15.21 (22.9)	3.41 (4.96)
T_3	UV light exposure at 200 kg/h feed rate for 45 min	0.00 (1.00)	0.21 (1.10)	0.22 (1.10)	0.52 (1.23)	1.04 (1.43)	1.19 (1.5)	1.27 (1.50)	0.97 (1.40)	1.71 (1.64)	2.44 (1.85)	10.75 (19.1)	13.30 (21.3)	2.80 (4.51)
T_4	UV light exposure at 200 kg/h feed rate for 60 min	0.00 (1.00)	0.21 (1.10)	0.21 (1.10)	0.42 (1.19)	0.95 (1.39)	0.72 (1.31)	0.94 (1.40)	0.96 (1.40)	1.57 (1.60)	1.87 (1.68)	6.75 (15)	8.72 (16.8)	1.94 (3.75)
T_5	UV light exposure at 350 kg/h feed rate for 15 min	0.43 (1.19)	0.52 (1.23)	0.47 (1.21)	0.94 (1.39)	1.52 (1.59)	2.21 (1.79)	1.90 (1.70)	2.36 (1.83)	3.59 (2.14)	5.75 (2.59)	21.45 (27.4)	23.30 (28.84)	5.37 (6.08)
T_6	UV light exposure at 350 kg/h feed rate for 30 min	0.22 (1.11)	0.42 (1.19)	0.44 (1.20)	0.78 (1.33)	1.42 (1.56)	1.69 (1.64)	1.67 (1.64)	2.10 (1.76)	3.22 (2.05)	4.00 (2.23)	18.98 (25.7)	20.62 (26.9)	4.63 (5.7)
T_7	UV light exposure at 350 kg/h feed rate for 45 min	0.21 (1.10)	0.42 (1.19)	0.43 (1.20)	0.68 (1.30)	1.41 (1.55)	1.61 (1.62)	1.61 (1.62)	1.88 (1.70)	2.44 (1.85)	3.75 (2.16)	17.37 (24.37)	18.65 (25.5)	4.21 (5.43)
T_8	UV light exposure at 350 kg/h feed rate for 60 min	0.21 (1.10)	0.37 (1.17)	0.42 (1.19)	0.63 (1.28)	1.26 (1.51)	1.35 (1.53)	1.37 (1.54)	1.40 (1.55)	2.15 (1.77)	3.35 (2.07)	15.65 (23.1)	17.18 (24.4)	3.78 (5.18)
T_9	UV light exposure at 500 kg/h feed rate for 15 min	0.53 (1.23)	0.63 (1.28)	0.64 (1.28)	1.04 (1.43)	1.69 (1.64)	2.40 (1.84)	2.13 (1.77)	2.58 (1.89)	4.12 (2.26)	8.26 (3.03)	33.90 (35.6)	35.97 (36.7)	7.82 (7.5)
T_{10}	UV light exposure at 500 kg/h feed rate for 30 min	0.47 (1.21)	0.59 (1.26)	0.58 (1.25)	0.96 (1.39)	1.62 (1.62)	2.33 (1.82)	2.02 (1.74)	2.57 (1.89)	3.71 (2.17)	6.49 (2.73)	29.75 (33.0)	31.49 (34.05)	6.88 (7.01)
T_{11}	UV light exposure at 500 kg/h feed rate for 45 min	0.53 (1.24)	0.64 (1.28)	0.65 (1.29)	1.14 (1.46)	1.80 (1.67)	2.63 (1.9)	1.72 (1.64)	2.84 (1.96)	4.14 (2.27)	9.33 (3.21)	36.61 (37.2)	41.92 (40.3)	8.66 (7.95)
T_{12}	UV light exposure at 500 kg/h feed rate for 60 min	0.63 (1.28)	0.64 (1.28)	0.97 (1.40)	1.17 (1.47)	2.00 (1.73)	2.78 (1.94)	2.51 (1.87)	3.01 (2.00)	4.78 (2.39)	13.51 (3.81)	38.78 (38.5)	42.45 (40.6)	9.44 (8.19)
T_{13}	Untreated Control	0.64 (1.28)	1.24 (1.50)	1.37 (1.54)	1.57 (1.6)	2.39 (1.84)	4.29 (2.29)	3.45 (2.1)	7.88 (2.98)	8.90 (3.14)	15.94 (4.10)	40.50 (39.5)	46.01 (42.7)	11.18 (8.71)
	SE (m±)	0.02	0.02	0.024	0.03	0.024	0.08	0.08	0.06	0.1	0.19	3.08	2.58	0.772
	CD at 5%	0.06	0.05	0.07	0.09	0.08	0.24	0.24	0.2	0.31	0.58	9.53	7.96	2.383
	CV	2.20	1.75	2.68	2.9	2.18	6.49	6.58	5.00	6.85	10.20	15.43	12.20	18.89

Table 3: Effect UV treatment on percent weight loss of pigeon pea over storage period

TR	Treatment Details	Percent weight loss												Mean
		15	30	45	60	75	90	105	120	135	150	165	180	
T_1	UV light exposure at 200 kg/h feed rate for 15 min	0.09 (1.05)	0.05 (1.03)	0.09 (1.04)	0.11 (1.06)	0.16 (1.08)	0.20 (1.09)	0.22 (1.11)	0.25 (1.12)	0.36 (1.17)	0.43 (1.19)	2.43 (1.84)	3.35 (2.08)	0.65 (1.24)
T_2	UV light exposure at 200 kg/h feed rate for 30 min	0.02 (1.01)	0.04 (1.02)	0.07 (1.03)	0.08 (1.04)	0.09 (1.04)	0.13 (1.06)	0.14 (1.07)	0.16 (1.08)	0.20 (1.09)	0.23 (1.11)	0.94 (1.39)	1.63 (1.62)	0.31 (1.12)
T_3	UV light exposure at 200 kg/h feed rate for 45 min	0.00 (1)	0.04 (1.02)	0.04 (1.02)	0.08 (1.04)	0.08 (1.04)	0.13 (1.06)	0.12 (1.06)	0.13 (1.07)	0.17 (1.08)	0.20 (1.09)	0.70 (1.30)	1.23 (1.49)	0.24 (1.10)
T_4	UV light exposure at 200 kg/h feed rate for 60 min	0.00 (1)	0.03 (1.02)	0.02 (1.01)	0.07 (1.03)	0.05 (1.03)	0.07 (1.03)	0.10 (1.05)	0.10 (1.05)	0.15 (1.07)	0.15 (1.07)	0.38 (1.17)	0.87 (1.36)	0.16 (1.07)
T_5	UV light exposure at 350 kg/h feed rate for 15 min	0.08 (1.04)	0.05 (1.03)	0.09 (1.04)	0.12 (1.06)	0.17 (1.08)	0.20 (1.10)	0.25 (1.12)	0.26 (1.12)	0.45 (1.2)	0.51 (1.23)	2.94 (1.98)	3.50 (2.11)	0.72 (1.25)
T_6	UV light exposure at 350 kg/h feed rate for 30 min	0.05 (1.03)	0.06 (1.03)	0.09 (1.04)	0.11 (1.05)	0.14 (1.07)	0.19 (1.09)	0.19 (1.09)	0.24 (1.12)	0.30 (1.14)	0.37 (1.17)	2.14 (1.77)	2.48 (1.86)	0.53 (1.21)
T_7	UV light exposure at 350 kg/h feed rate for 45 min	0.07 (1.03)	0.05 (1.03)	0.08 (1.04)	0.09 (1.04)	0.13 (1.07)	0.17 (1.08)	0.18 (1.09)	0.19 (1.09)	0.30 (1.14)	0.33 (1.15)	2.01 (1.73)	2.33 (1.83)	0.49 (1.19)
T_8	UV light exposure at 350 kg/h feed rate for 60 min	0.05 (1.03)	0.04 (1.02)	0.07 (1.03)	0.09 (1.04)	0.11 (1.05)	0.15 (1.07)	0.14 (1.07)	0.19 (1.09)	0.26 (1.12)	0.28 (1.13)	1.56 (1.60)	1.78 (1.66)	0.39 (1.16)
T_9	UV light exposure at 500 kg/h feed rate for 15 min	0.10 (1.05)	0.06 (1.03)	0.10 (1.05)	0.15 (1.07)	0.20 (1.10)	0.27 (1.13)	0.18 (1.09)	0.31 (1.15)	0.46 (1.21)	0.62 (1.27)	5.23 (2.47)	3.77 (2.18)	0.95 (1.32)
T_{10}	UV light exposure at 500 kg/h feed rate for 30 min	0.08 (1.04)	0.09 (1.05)	0.10 (1.05)	0.13 (1.06)	0.17 (1.08)	0.24 (1.12)	0.25 (1.12)	0.30 (1.14)	0.45 (1.20)	0.55 (1.25)	4.51 (2.34)	4.22 (2.28)	0.92 (1.31)
T_{11}	UV light exposure at 500 kg/h feed rate for 45 min	0.08 (1.04)	0.07 (1.03)	0.12 (1.06)	0.15 (1.07)	0.20 (1.05)	0.35 (1.16)	0.25 (1.12)	0.41 (1.19)	0.50 (1.22)	0.97 (1.40)	4.83 (2.40)	5.60 (2.57)	1.12 (1.36)
T_{12}	UV light exposure at 500 kg/h feed rate for 60 min	0.08 (1.04)	0.09 (1.05)	0.15 (1.08)	0.17 (1.08)	0.23 (1.11)	0.37 (1.17)	0.27 (1.13)	0.44 (1.2)	0.55 (1.25)	1.31 (1.52)	5.78 (2.60)	6.60 (2.76)	1.34 (1.42)
T_{13}	Untreated Control	0.11 (1.05)	0.15 (1.07)	0.20 (1.09)	0.22 (1.10)	0.33 (1.15)	0.48 (1.22)	0.36 (1.17)	0.54 (1.24)	0.68 (1.29)	2.56 (1.88)	7.58 (2.93)	9.36 (3.22)	1.88 (1.53)
SE (m)	SE (m±)	0.007	0.004	0.006	0.006	0.008	0.012	0.012	0.011	0.034	0.053	0.163	0.093	0.058
CD 5%	CD at 5%	0.022	0.013	0.019	0.019	0.024	0.037	0.037	0.034	0.106	0.164	0.502	0.286	0.179
CV	CV	0.989	0.563	0.852	0.837	1.032	1.543	1.554	1.373	4.16	5.94	11.71	6.31	10.96

Conclusion

Among the treatments, grains treated at lower feed rates (200 Kg/h) and longer exposure durations (60 min) showed the least insect damage (8.7%) and weight loss (0.9%) after 180 days of storage. The insect damage percentage and weight loss percentage in untreated sample was found high as 46% and 9.3% respectively. The UV treated grains were maintaining a lower moisture level as compared to untreated grains throughout storage period resulting moisture reduction due to UV Irradiation.

UV irradiation was found to be effective in reducing storage insect damage in pigeon pea. Low feed rate (200 kg/h) and long exposure time (60 min, T_4) was found to effective for management insect damage for period of 150 days storage. Thus, UV irradiation can be used with other control methods such as biological control in integrated pest management (IPM) of stored product pests and it may also provide a sustainable alternative for the control of other storage insect pests in near future.

Acknowledgements

We are very grateful to AICRP on Post-Harvest Engineering and Technology, and Department of Agricultural Process Engineering, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola for assisting with facilities required for completing the research work.

References

1. Azizoglu U, Yilmaz S, Karaborklu S, Ayvaz A. Ovicidal activity of microwave and UV radiations on Mediterranean flour moth *Ephestia kuehniella* Zeller, 1879 (Lepidoptera: Pyralidae). Turkiye Entomoloji Dergisi. 2011;35(3):437-446.
2. Directorate of Pulses Development. Annual Report 2022-23 (Technical Report No. DPD/Pub./TR/46/2022-23). Bhopal: Ministry of Agriculture & Farmers Welfare, Government of India; 2023.
3. Faruki SI, Das DR, Khan AR, Khatun M. Effect of ultraviolet (254 nm) irradiation on egg hatching and adult emergence of the flour beetles, *Tribolium castaneum*, *T. confusum* and the almond moth, *Cadra cautella*. Journal of Insect Science. 2007;7:1-6.
4. Guru PN, Dawang SP, Bidyalakshmi Devi T, Kaukab S, Vishwakarma RK, Kotwaliwale N. Manual and handheld guide on storage management of major legumes: study on determining storage losses of pulses stored in warehouses and to recommend norms for loss/gain during long term storage [ICAR-DoCA Project]. [n.d.].
5. Jawalekar KV, Baishya S, Rathi S, *et al.* Assessment of nutritional composition in prominent *Cajanus cajan* germplasm in India. International Journal of Current Microbiology and Applied Sciences. 2020;9(12):387-397.
6. Karthik R, Deka MK, Dumala S, Pamala PJ. Generation-wise comparative biology of pulse beetle, *Callosobruchus maculatus* on different stored pulses. Biological Forum-An International Journal. 2023;15(6):442-449.
7. Mishra Y, Mishra V. Eco-friendly techniques against pulse beetle in seeds under storage: an insight. International Journal of Zoological Investigations. 2021;7(2):733-739.
8. Nakambam S, Singh PP, Kumar N, Ahmad MA, Ningthoujam K, Biswas D, Sangjukta I, Patel YK. Estimation of grain damage and weight loss by *Callosobruchus chinensis* L. in pigeon pea in storage. The Pharma Innovation Journal. 2022;11(8):1758-1762.
9. Poushand F, Amanieh S, Forouzan M. Effect of ultraviolet light (UV-C) in different times and heights on adults stage of whitefly (*Trialeurodes vaporariorum*). Journal of Entomology and Zoology Studies. 2017;5(4):858-862.
10. Sarkar S, Panda S, Yadav KK, Kandasamy P. Pigeon pea (*Cajanus cajan*) is an important food legume in Indian scenario—A review. Legume Research: An International Journal. 2020;43(5):601-610.
11. Sedaghat R, Talebi AA, Moharramipour S. Effects of ultraviolet irradiation on life table of cowpea weevil, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of the Entomological Research Society. 2014;16(2):1-12.
12. Sedehi A, SS MN, Karbalaizadeh M. Effect of ultraviolet irradiation (254 nm) on egg hatching, population growth and reproductive parameters of cowpea weevil, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of Entomology and Zoology Studies. 2014;3(5):476-482.
13. Sheeja HC, Jones SRD. Effect of UV radiation on hatchability in different ages of *C. cephalonica* (Stainton) (Lepidoptera: Pyralidae). Journal of Entomology and Zoology Studies. 2015;3(2):118-120.
14. Singh D, Singh DV, Singh G, Singh H, Singh G. Biological control of *Callosobruchus maculatus* (F.) in stored pigeonpea *Cajanus cajan* (L.). Biological Forum-An International Journal. 2023;15(8a):233-237.
15. Susmitha D, Kalaimagal T, Senthil R, *et al.* Grain nutrients variability in pigeonpea genebank collection and its potential for promoting nutritional security in dryland ecologies. Frontiers in Plant Science. 2022;13:934296.
16. Talari A, Shakappa D. Role of pigeon pea (*Cajanus cajan* L.) in human nutrition and health: a review. Asian Journal of Dairy and Food Research. 2018;37(3):212-220.