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Best time of spraying irradiated carrageenan on the growth, yield and root nodulation of Mungbean [*Vigna radiata* (L.) Wilczek]

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Key words: Foliar fertilizer, Irradiated carrageenan, Mungbean, Root nodulation, Seed yield, Spraying time

Abstract

Applying potential foliar fertilizer for mungbean at the best time can help farmers increase their yield and, subsequently, their income. Hence, the study was conducted to determine the growth, yield, and root nodulation performance of mungbean as influenced by the time of spraying irradiated carrageenan. The study was conducted at Candon City, Ilocos Sur, Philippines from January to May 2021 employing Randomized Complete Block Design with three blocks. The experimental treatments were as follows: T0: no application (control); T1: spraying at 6 a.m.; T2: spraying at 7 a.m.; T3: spraying at 8 a.m.; T4: spraying at 3 p.m.; T5: spraying at 4 p.m.; and T6: spraying at 7 p.m. The result of the study revealed significant differences in terms of survival rate (%), but no significant differences were noted in terms of number of days to emergence, flowering, and maturity, plant height at maturity (cm), number of pods per plant, length of the pod (cm), number of seeds per pod, weight of 100 seeds (g), plant growth and vigor, nodule abundance and color, nodule position, and effective nodulation assessment. Spraying of irradiated carrageenan at 8 a.m. produced the highest seed yield per hectare (2514.00kg) however, did not vary significantly with other spraying times. It was noted that spraying irradiated carrageenan can increase the yield of mungbean by 9.95% to 28.57%. The result suggests that irradiated carrageenan can be sprayed early in the morning (6 a.m. to 8 a.m.) and late in the afternoon to early evening (3 p.m. to 7 p.m.) by the farmers in the locality. Seed inoculation should also be done by the farmers to improve the root nodulation of mungbean plants.

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Introduction

Legumes are the second most important food source in the world, after cereals (Elobuike *et al.,* 2021). Legumes are inexpensive, healthy sources of protein, fiber, and micronutrients (Semba *et al.,* 2021). Integrating grain legumes in the crop rotation plan can also improve soil fertility through the symbiotic association with microorganisms such as rhizobia (Kebede 2021) (Stagnari *et al.,* 2017) (Nanganoa *et al.,* 2019) (Crews and Peoples 2004) hence, requires lesser or no fertilizer application (Peoples *et al.,* 2019) (Montana State University 2010) while increasing the yield and income (Feng *et al.,* 2021) (Shah *et al.,* 2021). Production of legumes has expanded from 150 million tons to 300 million tons worldwide, with a modest yield increase of 0-2% per year (Maduraimuthu *et al.,* 2023) in an area of about 81 million ha (Dutta *et al.,* 2022). China, Myanmar, Canada, Australia, Brazil, Argentina, the United States, and Russia are the main producers of grain legumes (Dutta *et al.,* 2022) with India as the highest producer (Dogan 2020) (Smith *et al.,* 2018). About 20% of this total production is made up of legumes like mungbean (Maduraimuthu *et al.,* 2023) (Foyer *et al.,* 2016). Mungbean (*Vigna radiata* (L.) Wilczek) is one of the most important legume crops in South and Southeast Asia (Dahiya *et al.,* 2015) (Hou *et al.,* 2019). It belongs to the Fabaceae or Leguminosae family of plants commonly known as the legume, pea, or bean family (Dogan 2020) (Yin *et al.,* 2021). Mungbean is considered a native crop of the Indian subcontinent (Pratap *et al.,* 2021). The world's mungbean production is estimated to be 5.3 million tons, with India and Myanmar contributing around 30% each, China 16%, and Indonesia 5% of the total production, which is grown over an area of roughly 7.3 million ha. Mungbean has also significant export potential and consistent farm gate pricing due to its great demand around the world (Nair 2022). Although global grain legume production is increasing, the current average yield per hectare has been low with less than 1 ton ha-1, for some reasons, including inadequate knowledge of new cultivars and crop management practices (Rahmianna *et al.,* 2021) (World Vegetable Center 2016).

In the Philippines, mungbean or locally known as *munggo* is considered the cheapest source of protein diet of Filipinos (SunStar 2014). It serves as a raw ingredient in the processing of sotanghon, hopia, piyaya, mungbean sprouts, and foods such as soups, porridge, bread, noodles, and ice cream. It can be used as an intercrop, rotation crop, or relay crop due to its favorable agronomic properties. Additionally, its crop leftovers can be utilized as fodder (Department of Agriculture-Bureau of Plant Industry 2010). Mungbean can be grown year-round, but it performs best when harvesting coincides with dry periods (Medenilla 2017) (Hermoso 2022). It can be grown after rice, which presents a good opportunity for farmers to earn additional income because its production requires minimal inputs and it is a short-duration crop that can contribute millions of pesos to the local economy. Ilocos Region with around 35% share is the top producer of the crop followed by Central Luzon (22%), Cagayan Valley (14%), Western Visayas (8%), and BARMM (8%) (Varcas 2021)(Philippine Statistics Authority 2021). Despite the slight increase in the country's mungbean production over the past years, the average yield per hectare is still very low (Gatan *et al.,* 2019) (Philippine Statistics Authority 2021) with an average yield per hectare of 800 to 1,000 kilos (Serquina 2018). The shortage of high-quality seeds, mungbean plant sensitivity to various pests, poor management practices, and most importantly, the low levels of domestic production all have an impact on the country's mungbean production (Domingo 2023) (Yap 2018) (Gatan *et al.,* 2019). These triggered the country to import mungbean to augment domestic demands (Macapagal 2023). Hence, there is a need for continuous exploration and development of technologies that are adaptive to the present conditions.

Foliar spraying is a well-known method for applying fertilizer; it involves nutrient-direct entrance through the stomatal opening of the leaves. Recent research suggests that its use aids in plants' ability to adapt to specific environmental challenges such as increased tolerance of mungbean plants to drought stress (Reyes *et al.,* 2018) (Maduraimuthu *et al.,* 2023). One of the developed foliar fertilizer technologies is irradiated carrageenan. Irradiated carrageenan is a foliar fertilizer derived from seaweed extract called carrageenan processed through gamma radiation to reduce its molecular weight thereby increasing effectiveness. The technology is gaining popularity due to its commendable effects on the growth and yield of crops. In rice, the application of irradiated carrageenan can increase the number of tillers, produce more extensive root growth, prevent lodging, make plants more resistant to biotic and abiotic stress such as tungro virus and typhoon, and increase yield by 20-30% and (Gil 2018) (Abad *et al.,* 2018) (Shukla *et al.,* 2016).

Irradiated carrageenan was also observed to improve the growth, hasten harvesting, and increase the yield of cherry tomatoes (Pamati-an *et al.,* 2023). Another study showed irradiated carrageenan to improve *Catharanthus roseus* (L.) G. Don, a medicinal plant that produces indole alkaloids used in cancer chemotherapy (Naeem *et al.,* 2015). Foliar fertilizer is a potent technique for swiftly and efficiently supplying nutrients to plants. However, it's crucial to time the application of foliar nutrients properly to obtain the greatest benefit from them.

Hence, this study was conducted to evaluate the performance of mungbean applied with irradiated carrageenan at different times. Specifically, this aimed to evaluate the effects of irradiated carrageenan in terms of number of days to emergence, flowering, and maturity, plant height at maturity (cm), number of pods per plant, length of the pod (cm), number of seeds per pod, weight of 100 seeds (g), plant growth vigor, nodule abundance and color, nodule position, effective nodulation assessment, and seed yield per hectare (kg).

Material and methods

Experimental materials

The mungbean seeds of the Labo variety were procured in San Nicolas, Metro Manila, Philippines while the irradiated carrageenan was obtained from the Department of Science and Technology Region I (DOST-I), Candon City, Ilocos Sur, Philippines. Other materials for the study were secured locally.

Experimental location, design, and treatments

The experimental area was located at Barangay Talogtog, Candon City, Ilocos Sur, Philippines from January to May 2021, which has GPS coordinates of 17°12'11.2"N 120°25'47.0"E at an elevation of about 3 m above sea level (Fig. 1). The experiment was laid out in a 234m² area divided into 3 blocks following the Randomized Complete Block Design (RCBD). Each block was subdivided into 7 equal plots corresponding to the seven treatments or the time of spraying of irradiated carrageenan as follows: T0: no application (control); T1: spraying at 6 a.m.; T2: spraying at 7 a.m.; T3: spraying at 8 a.m.; T4: spraying at 3 p.m.; T5: spraying at 4 p.m.; and T6: spraying at 7 p.m.

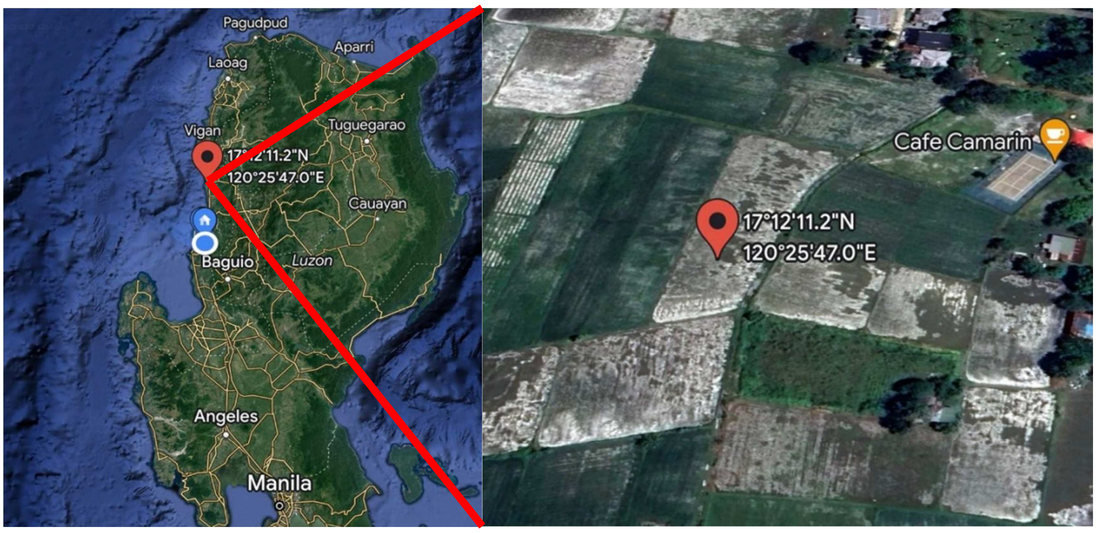

Fig. 1. A satellite image showing the location of the experimental area taken from Google Map.

Land preparation

A land with a total area of 234m² was thoroughly plowed and harrowed using a tractor-drawn rotavator. Plots were laid out having a dimension of 2m x 5m each. A 0.5m space was provided between plots in each block to ease carrying-out field operations. Four furrows were made on each plot spaced at 50cm. Twenty-five-centimeter space was provided on both sides of the plots before the construction of furrows.

Planting and thinning

The mungbean seeds were drilled in furrows at 20-22 seeds per linear meter. Each furrow was planted with 100 to 110 seeds having a total of 400 to 440 seeds per plot. Seedlings emerged 4 days after sowing in all treatments. Thinning was done after two weeks from sowing, leaving 100 healthy mungbean plants per furrow, or a total of 400 plants per plot. Plants flowered 32 days after the sowing of seeds.

Fertilizer application and spraying of irradiated carrageenan

Fertilizer was applied based on the recommended rate of 50-50-7kg of N, P, and K/ha. This was side-dressed 14 days after planting. The irradiated carrageenan was sprayed at different times at 6 a.m., 7 a.m., 8 a.m., 3 p.m., 4 p.m., and 7 p.m., which corresponds to the treatments. It was sprayed at 10, 20, 30, and 40 days after planting at a rate of 160 ml/16 L, or 6 L/ha.

Weeding and irrigating the plants

Weeds were removed manually as they grew to avoid competition for light, water, nutrients, and space and act as hosts for insect pests and diseases. Furrow irrigation was done after planting, during germination, and after fertilizer application. Flood irrigation was employed during the blooming stage, pod development, and seed-filling stages and was terminated 15 days prior to harvesting.

Pest management

Pests were controlled employing physical methods through manual picking of insect pests and removing diseased plants and chemical methods through spraying insecticides such as Sevin WP85 following the manufacturer's recommendation.

Harvesting and postharvest handling

Mungbean plants that showed signs of maturity, as manifested by 75% of the pods turning black, were harvested. The plants uniformly matured 55 days after the sowing of seeds. Harvesting mature pods was done by hand-picking early in the morning or late in the afternoon to minimize shattering. Three primings were done at a one-week interval. The harvested pods were immediately sun-dried for a day to facilitate threshing by foot trampling and cleaning through winnowing. The seeds were further sundried for three consecutive days to attain 12% moisture content for longer shelf life and storage.

Data gathered

The following data were gathered; (1) days to emergence, was recorded by counting the number of days from sowing until approximately 50% of the seedlings in a plot had emerged; (2) days to flowering, recorded by counting the number of days from sowing to the day when approximately 50% of the plants in a plot flowered; (3) days to maturity, recorded by counting the number of days from sowing to the day when approximately 50% of the plants in a plot produced matured pods; (4) plant height at maturity (cm), which was taken by measuring 10 samples plants vertically from ground level to the tip of the main stem at maturity using meterstick divided by 10 to get the average; (5) survival rate (%), of which the number of survived plants per plot at harvesting was counted divided by the 400 (plants per plot after thinning) multiplied by 100; (6) number of pods per plant, was determined by counting the number of developed pods from 10 of the sample plants per plot, divided by 10; (7) length of the pod (cm), was taken by measuring the base to the tip of the 10 randomly selected pods from the 10 sample plants in centimeters using foot ruler, divided by 10; (8) number of seeds per pod, was obtained by counting the number of seeds of 10 randomly selected mature pods from 10 sample plants per plot, divided by 10 to get the average; (9) weight of 100 seeds (g), was taken by weighing 100 randomly selected seeds from each plot in grams; (10) seed yield per hectare (kg), this was taken by extrapolating the seed yield per plot (g) into seed yield per hectare (kg) using the formula: Yield inkg per hectare = (Yield per plot (kg) x Area/hectare)/Area per plot and plant growth and vigor, nodules abundance and color, nodule position, and effective nodulation assessment following the Nodulation and Nitrogen Fixation Field Assessment Guide by (Risula 2019).

Data analysis

The data gathered were subjected to Analysis of Variance (ANOVA) in Randomized Complete Block Design (RCBD) with 3 blocks. The significant difference between means was further tested using Tukey's Honest Significant Difference (HSD) Test at 5% and 1% levels of significance. The IRRI-STAR application was used to analyze the data.

Result and discussion

The growth and yield parameters such as plant height (cm), pods per plant, length of pod (cm), seeds per pod, survival rate (%), weight of 100 seeds (g), and seed yield per hectare (kg) are presented in Table 1.

Table 1. Growth and yield performance of mungbean sprayed with irradiated carrageenan at different times. Barangay Talogtog, Candon City, Ilocos Sur, Philippines.

Time of Spraying Irradiated Carrageenan	Plant height (cm)	Pods per plant	Length of pod (cm)	Seeds per pod	Survival rate (%)	Weight of 100 seeds (g)	Seed yield per hectare (kg)
No application (control)	55.97	19.13	9.98	11.53	96.67[abc]	8.67	1955.33
Spraying at 6 a.m.	59.50	20.97	11.27	12.63	94.67[bc]	9.67	2202.33
Spraying at 7 a.m.	58.93	18.03	10.45	12.40	96.67[abc]	8.67	2189.33
Spraying at 8 a.m.	55.97	18.77	10.68	11.70	93.67[c]	8.33	2514.00
Spraying at 3 p.m.	49.50	20.67	11.24	12.77	96.33[abc]	9.00	2245.33
Spraying at 4 p.m.	53.13	18.27	10.89	12.63	98.33[a]	9.00	2150.00
Spraying at 7 p.m.	60.90	17.43	11.80	12.57	97.00[ab]	9.33	2290.00
F-test	0.0926	0.5572	0.0992	0.1851	0.0033	0.6294	0.4375
C.V. (%)	7.90	13.15	6.21	5.20	1.11	10.10	12.69

Plant height at maturity

The plant height (cm) of mungbean plants, as influenced by time of irradiated carrageenan spraying, showed that plants sprayed at 7 p.m. produced the tallest plants with a mean of 60.90cm followed by plants sprayed at 6 a.m. with a mean of 59.50cm, followed by plants sprayed at 7 a.m. with a mean of 58.93cm, followed by plants sprayed at 8 a.m. with a mean of 55.97cm while plants sprayed at 3 p.m. produced the shortest plants with a mean of 49.50cm. However, analysis of variance revealed no significant result.

Pods per plant

As to pods per plant, the result showed that mungbean plants sprayed at 6 a.m. produced the most pods per plant with a mean of 20.97 followed by mungbean plants sprayed at 3 p.m. with a mean of 20.67. This was followed by plants that were not applied with irradiated carrageenan (control) with a mean of 19.12. The least number of pods per plant was observed from plants sprayed at 7 p.m. with a mean of 17.43. However, analysis of variance revealed that the number of pods per plant was not significantly different.

Length of pod

The length of pod (cm) of mungbean, as influenced by time of irradiated carrageenan spraying, showed that plants sprayed at 7 p.m. produced longest pods with a length of 11.80cm followed by mungbean plants sprayed at 6 a.m. with a mean of 11.27cm followed by plants sprayed at 3 p.m. with a mean of 11.24cm while the shortest pods were produced from plants that were not applied with irradiated carrageenan (control) with a mean of 9.98cm. However, the analysis of variance revealed no significant differences between mungbean plants sprayed with irradiated carrageenan at different times.

Seeds per pod

The seeds per pod of the mungbean plants sprayed with irradiated carrageenan at different time revealed that spraying at 3 p.m. produces the highest seeds per pod (12.77) followed by spraying at 6 a.m. (12.63) and spraying at 4 p.m. (12.63), spraying at 7 p.m. (12.57), spraying at 7 a.m. (12.40). No application of irradiated carrageenan produces the lowest seeds per pod (11.53). However, the result disclosed no significant differences between the different times of spraying irradiated carrageenan on mungbean.

Survival rate

The result showed a highly significant difference in the survival rate (%) of mungbean sprayed at the different times with irradiated carrageenan. The mungbean plants sprayed at 4 p.m. gave the highest survival rate (98.33%) but were statistically comparable to plants that were not applied with irradiated carrageenan (96.67%), plants sprayed at 7 a.m. (96.67%), at 3 p.m. (96.33%) and 7 p.m. (97.00%). The mungbean plants sprayed at 8 a.m. gave the lowest survival rate (93.37%) but were statistically comparable to plants that were not applied with irradiated carrageenan (96.67%), plants sprayed at 6 a.m. (94.67%), at 7 a.m. (96.67%), and at 3 p.m. (96.33%).

Weight of 100 seeds

The weight of 100 seeds (g) of mungbean plants sprayed with irradiated carrageenan at different times showed that spraying at 6 a.m. produced the heaviest 100 seed weight (9.67g) followed by spraying at 7 p.m. (9.33g), spraying at 3 p.m. and at 4 p.m. with both means of 9.00g, spraying at 7 a.m. and no irradiated carrageenan spraying with both means of 8.67g. the lightest were produced from mungbean plants sprayed at 8 a.m. (8.33). However, the analysis of variance disclosed no significant differences between the different treatments of the study.

Seed yield per hectare

The seed yield per hectare (kg) of the mungbean plants sprayed with irradiated carrageenan at different times showed that plants sprayed at 8 a.m. produced the highest seed yield with a mean of 2514.00kg. It was followed by plants sprayed at 7 p.m. (2290.00kg), at 3 p.m. (2245.33kg), at 6 a.m. (2202.33kg), and plants sprayed at 7 a.m. (2189.33kg). Mungbean plants that were not sprayed with irradiated carrageenan produced the lowest seed yield with a mean of 1955.33kg. The analysis of variance showed that the seed yield per hectare was not significantly different. However, it can be noted that spraying irradiated carrageenan can increase the yield of mungbean by 9.95% to 28.57%. The result suggests that a higher yield can be obtained by spraying irradiated carrageenan early in the morning, late in the afternoon, or early evening. The result of the study supports the claim of Verma *et al.* (2013) that early hours in the morning and in the evening when the temperature is low is the best time for foliar fertilizer application. There is less risk of burning the leaves from direct sunlight since the spray deposit dissipates more slowly. Because of the high humidity in the evenings and at night, nutrients from dried spray deposits break down and can then be absorbed by leaves. Kumar *et al.* (2020) mentioned that foliar spraying is most profitable when done late at night and early in the morning. A study by Muraoka and Neptune (1977) has also shown that spraying foliar fertilizer early in the morning can prevent leaf injury.

Effective nodule assessment

The effective nodulation assessment parameters such as plant growth and vigor, nodulation abundance and color, nodule position, and total score are presented in Table 2. The result showed that spraying of irradiated carrageenan at different times did not vary significantly in terms of plant growth and vigor, nodulation abundance and color, nodule position, and total score with means ranging from 4.50 to 4.87, 2.73 to 3.40, 1.80 to 2.33, and 9.40 to 10.43, respectively. Based on the total score, mungbean plants grown at Barangay Talogtog, Candon City, Ilocos Sur, Philippines sprayed with irradiated carrageenan at different times were found to have nodules present with limited nitrogen fixing potential. The result suggests that beneficial bacteria for root nodulation of mungbean plants are limited in the area. Root nodulation is the result of an effective symbiotic relationship between the mungbean plants and the rhizobium bacteria present in the soil (Stacey 2007). One way to increase root nodulation is the introduction of rhizobium bacteria through seed inoculation. Studies showed that seed inoculation can significantly improve the root nodulation, growth, and yield of mungbean plants (Matkarimov *et al.,* 2019) (Ather Nade *et al.,* 2003). Further, seed inoculation should be done in fields where mungbean cultivation is taken up for the first time (Nair *et al.,* 2011).

Table 2. Nodulation Characteristics of mungbean sprayed with irradiated carrageenan at different times. Barangay Talogtog, Candon City, Ilocos Sur, Philippines.

Time of Spraying Irradiated Carrageenan	Plant Growth and Vigor	Nodule Abundance and Color	Nodule Position	Total Score	Effective Nodulation Assessment/Remarks
No application (control)	4.73	3.40	2.13	10.27	Nodules present with limited nitrogen fixing potential
Spraying at 6 a.m.	4.50	2.90	2.27	9.83	
Spraying at 7 a.m.	4.73	2.90	2.23	9.73	
Spraying at 8 a.m.	4.60	2.83	2.20	9.80	
Spraying at 3 p.m.	4.83	3.20	2.33	10.43	
Spraying at 4 p.m.	4.87	2.73	2.13	9.73	
Spraying at 7 p.m.	4.80	2.73	1.80	9.40	
F-test	0.4682	0.9039	0.7471	0.9208	-
C.V. (%)	4.82	25.27	18.39	11.07	-

Effective nodulation assessment scale by Risula (2019)

Total	Description	Effective nodulation assessment Remarks
11-13	Effective nodulation	Numerous nodules that have good nitrogen-fixing potential
7-10	Nodulation less effective	Nodules present with limited nitrogen-fixing potential
1-6	Poor nodulation	Few nodules present with very little to no nitrogen-fixation potential

Agro-meteorological Data

The average monthly minimum and maximum temperature (°C), relative humidity (%), and rainfall (mm) during the study is presented in Fig. 2. The temperature during the study ranges from 23.06°C to 33.89°C. The highest minimum and maximum temperatures were recorded in May at 25.01°C and 33.89°C, while the lowest minimum and maximum temperatures were recorded in April at 23.06°C and 31.12°C.

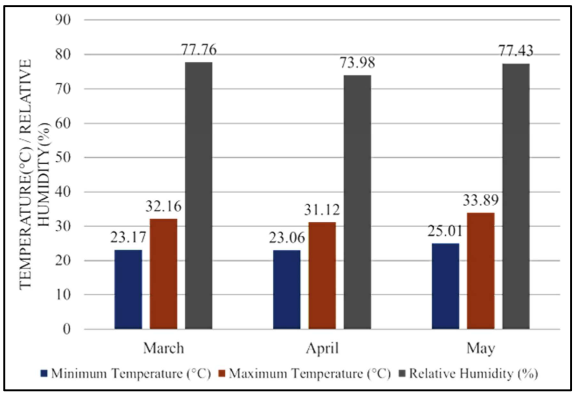

Fig. 2. Agro-meteorological data (temperature and relative humidity) during the conduct of the study.

The relative humidity during the study ranges from 73.98% to 77.76%. The total rainfall accumulated was 0.76mm. The agro-meteorological data were collected from DMMMSU-PAGASA Agro-met Station at Don Mariano Marcos Memorial State University- North La Union Campus (DMMMSU-NLUC), Sapilang, Bacnotan, La Union, Philippines.

Conclusion

Based on the result of the study, it is concluded that spraying of irradiated carrageenan at different times did significantly affect the number of days to emergence, flowering, and maturity, plant height at maturity, number of pods per plant, length of the pod, number of seeds per pod, weight of 100 seeds, plant growth and vigor, nodule abundance and color, nodule position, and effective nodulation assessment of mungbean plants. Spraying of irradiated carrageenan at 8 a.m. produced the highest seed yield per hectare (2514.00kg) however, did not vary significantly with other spraying times. Spraying irradiated carrageenan can increase the yield of mungbean by 9.95% to 28.57%. Mungbean plants grown at Barangay Talogtog, Candon City, Ilocos Sur, Philippines have nodules present with limited nitrogen fixing potential.

Recommendation(S)

Based on the result, irradiated carrageenan can be sprayed on mungbean plants early in the morning (6 a.m. to 8 a.m.), and late in the afternoon to early evening (3 p.m. to 7 p.m.) by the farmers at Barangay Talogtog, Candon City, Ilocos Sur, Philippines but best when sprayed at 8 a.m. Seed inoculation should also be done by the farmers to improve the root nodulation of mungbean plants.

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APPENDIX- A

Summary Data Tables and Results of Statistical Analysis from IRRI-STAR v 2.0.1

Appendix A.1. Mean Number of Days to Emergence of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	4	4	4	12	4
T1	4	4	4	12	4
T2	4	4	4	12	4
T3	4	4	4	12	4
T4	4	4	4	12	4
T5	4	4	4	12	4
T6	4	4	4	12	4
Block Total	28	28	28		
Grand Total				84	
Grand Mean					4

Appendix A.2. Mean Number of Days to Flower of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	32	32	32	96	32
T1	32	32	32	96	32
T2	32	32	32	96	32
T3	32	32	32	96	32
T4	32	32	32	96	32
T5	32	32	32	96	32
T6	32	32	32	96	32
Block Total	224	224	224		
Grand Total				672	
Grand Mean					32

Appendix A.3. Mean Number of Days to Maturity of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	55	55	55	165	55
T1	55	55	55	165	55
T2	55	55	55	165	55
T3	55	55	55	165	55
T4	55	55	55	165	55
T5	55	55	55	165	55
T6	55	55	55	165	55
Block Total	385	385	385		
Grand Total				1155	
Grand Mean					55

Appendix A.4. Mean Number of Plant Height at Maturity of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	58	54.7	55.2	167.9	55.97
T1	50.4	66.7	61.4	178.5	59.5
T2	53.9	58.1	64.8	176. 8	58.93
T3	51.8	53.7	62.4	167.9	55.97
T4	43.3	53.4	51.8	148.5	49.5
T5	48.4	60	51	159.4	53.13
T6	60.3	61.2	61.2	183.7	61.23
Block Total	366.1	407.8	407.8		
Grand Total				1182.7	
Grand Mean					56.31

Appendix A.4a. Analysis of Variance on the Plant Height at Maturity of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	165.6086	82.8043	4.19	0.0416*
Treatments	6	284.4562	47.4094	2.40	0.0926ns
Error	12	236.8981	19.7415		
Total	20	686.9629			

*= significant ns= not significant cv-7.90%

Appendix A.5. Mean Number of Survival Rate of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	97	96	97	290	96.67
T1	96	95	93	284	94.67
T2	98	96	96	290	96.67
T3	93	95	93	281	93.67
T4	96	96	97	289	96.33
T5	99	99	97	295	98.33
T6	96	98	97	291	97
Block Total	675	675	670		
Grand Total				2020	
Grand Mean					96.19

Appendix A.5a. Analysis of Variance on the Survival Rate of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	2.3810	1.1905	1.05	0.3803[ns]
Treatments	6	43.2381	7.2063	6.35	0.0033**
Error	12	13.6190	1.1349		
Total	20	59.2381			

ns=not significant **= highly significant cv-1.11%

Appendix A.6. Mean Number of Reaction to Insect Pest of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	1	1	1	3	1.5
T1	1	1	1	3	1.5
T2	1	1	1	3	1.5
T3	1	1	1	3	1.5
T4	1	1	1	3	1.5
T5	1	1	1	3	1.5
T6	1	1	1	3	1.5
Block Total	7	7	7		
Grand Total				21	
Grand Mean					10.5

Appendix A.7. Mean Number of Reaction to Disease of Mungbean. as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	1	1	1	3	1.5
T1	1	1	1	3	1.5
T2	1	1	1	3	1.5
T3	1	1	1	3	1.5
T4	1	1	1	3	1.5
T5	1	1	1	3	1.5
T6	1	1	1	3	1.5
Block Total	7	7	7		
Grand Total				21	
Grand Mean					10.5

Appendix A.8. Mean Number of Number of Pods per Plant of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	18	20.3	19.1	57.4	19.13
T1	23.3	20.1	19.5	62.9	20.97
T2	16.4	15.3	22.4	54.1	18.03
T3	16.6	16.6	23.1	56.3	18.77
T4	21	20.3	20.7	62	20.67
T5	21.9	16.2	16.7	54.8	18.27
T6	18.3	16.1	17.9	52.3	17.43
Block Total	135.5	124.9	139.4		
Grand Total				400.3	
Grand Mean					19.04

Appendix A.8a. Analysis of Variance on the Number of Pods per Plant of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	16.0867	8.0433	1.28	0.3125 [ns]
Treatments	6	31.9029	5.3171	0.85	0.5572 [ns]
Error	12	75.2000	6.2667		
Total	20	123.1895			

ns=not significant cv-13.15%

Appendix A.9. Mean Number of Length of the Pod of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	9.83	10.17	9.95	29.95	9.98
T1	11.88	11.38	10.55	33.81	11.27
T2	10.8	10.15	10.4	31.35	10.45
T3	11.24	10	10.8	32.04	10.68
T4	12.41	10.93	10.37	33.71	11.24
T5	10.72	11.73	10.21	32.66	10.89
T6	11.39	12.96	11.04	35.39	11.80
Block Total	78.27	77.32	73.27		
Grand Total				228.91	
Grand Mean					10.90

Appendix A.9a. Analysis of Variance on the Length of the Pod of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	1.9717	0.9858	2.15	0.1594 [ns]
Treatments	6	6.4368	1.0728	2.34	0.0992 [ns]
Error	12	5.5058	0.4588		
Total	20	13.9143			

ns=not significant cv-6.21%

Appendix A.10. Mean Number of Number of Seeds per Pod of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	11.1	11.6	11.9	24.6	8.2
T1	13.1	12.7	12.1	37.9	12.63
T2	13	12.1	12.1	37.2	12.4
T3	12.4	11.3	11.4	35.1	11.7
T4	13.7	12.3	12.3	38.3	12.77
T5	12.7	12.8	12.4	37.9	12.63
T6	11.8	13.8	12.1	37.7	12.57
Block Total	87.8	86.6	84.3		
Grand Total				248.7	
Grand Mean					11.84

Appendix A.10a. Analysis of Variance on the Number of Seeds per Pod of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	0.9038	0.4519	1.10	0.3642 ns
Treatments	6	4.3990	0.7332	1.78	0.1851 ns
Error	12	4.9295	0.4108		
Total	20	10.2324			

ns=not significant cv-5.20%

Appendix A.11. Mean Number of Weight of 100 Seeds of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
T0	9	8	9	26	8.67
T1	10	9	10	29	9.67
T2	8	9	9	26	8.67
T3	9	7	9	25	8.33
T4	10	8	9	27	9
T5	8	9	10	27	9
T6	10	10	8	28	9.33
Block Total	64	60	64		
Grand Total				188	
Grand Mean					8.95

Appendix A.11a. Analysis of Variance on the Weight of 100 Seeds of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	1.5238	0.7619	0.93	0.4205 ns
Treatments	6	3.6190	0.6032	0.74	0.6294 ns
Error	12	9.8095	0.8175		
Total	20	14.9524			

ns=not significant cv-10.10%

Appendix A.12. Mean Number of Seed Yield of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
T0	1924	2028	1914	5866	1955.33
T1	2628	1734	2245	6607	2202.33
T2	2118	2064	2386	6568	2189.33
T3	2568	2476	2498	7542	2514
T4	2582	2158	1996	6736	2245.33
T5	2428	2444	1578	6450	2150
T6	2348	2126	2396	6870	2290
Block Total	14014	15030	15022		
Grand Total				46639	
Grand Mean					2220.90

Appendix A.12a. Analysis of Variance on the Seed Yield of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	236120.6667	118060.3333	1.49	0.2652 ns
Treatments	6	504519.1429	84086.5238	1.06	0.4375 ns
Error	12	953828.0000	79485.6667		
Total	20	1694467.8095			

ns=not significant cv-12.69%

Appendix A.13. Mean Number of Plant Growth Vigor of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
T0	4.5	4.7	5	14.2	4.73
T1	4.5	4.5	4.5	13.5	4.5
T2	4.8	4.9	4.5	14.2	4.73
T3	5	4.7	4.1	13.8	4.6
T4	5	4.8	4.7	14.5	4.83
T5	5	4.5	4.6	14.1	4.7
T6	4.8	4.8	4.8	14.4	4.8
Block Total	33.6	32.9	32.2		
Grand Total				98.7	
Grand Mean					4.70

Appendix A.13a. Analysis of Variance on the Plant Growth Vigor of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	0.1638	0.0819	1.58	0.2464 ns
Treatments	6	0.3114	0.0519	1.00	0.4682 ns
Error	12	0.6229	0.0519		
Total	20	1.0981			

ns=not significant cv-4.82%

Appendix A.14. Mean Number of Nodules Abundance in Color of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
T0	3.4	3.2	3.6	10.2	3.4
T1	2.2	3.8	2.7	8.7	2.9
T2	2.9	2.6	3.2	8.2	2.73
T3	2.6	2.9	3	8.5	2.83
T4	4.2	3.6	1.8	9.6	3.2
T5	3.6	2	2.6	8.2	2.73
T6	3.6	2	2.6	8.2	2.73
Block Total	22.5	20.1	19.5		
Grand Total				61.6	
Grand Mean					2.93

Appendix A.14a. Analysis of Variance on the Nodules Abundance in Color of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	0.7200	0.3600	0.64	0.5420 ns
Treatments	6	1.1314	0.1886	0.34	0.9039 ns
Error	12	6.7000	0.5583		
Total	20	8.5514			

ns=not significant cv-25.27%

Appendix A.15. Mean Number of Nodule Position of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	2.2	1.8	2.4	6.4	2.13
T1	2	2.6	2.2	6.8	2.27
T2	2.1	2	2.6	6.7	2.23
T3	2.2	2.4	2	6.6	2.2
T4	2.8	2.6	1.6	7	2.33
T5	2.4	2.4	1.6	6.4	2.13
T6	1.8	1.6	2	5.4	1.8
Block Total	15.5	15.4	14.4		
Grand Total				45.3	
Grand Mean					2.16

Appendix A.15a. Analysis of Variance on the Nodule Position of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	0.1057	0.0529	0.34	0.7211 ns
Treatments	6	0.5381	0.0897	0.57	0.7471 ns
Error	12	1.8876	0.1573		
Total	20	2.5314			

ns=not significant cv-18.39%

Appendix A.16. Mean Number of Total Nodule Assessment of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Treatments	Block			Total	Mean
	I	II	III		
To	10.1	9.7	11	30.8	10.27
T1	8.7	11.4	9.4	29.5	9.83
T2	9.8	9.5	9.9	29.2	9.73
T3	9.8	10.2	9.4	29.4	9.8
T4	12	11	8.3	31.3	10.43
T5	10.8	9.4	9	29.2	9.73
T6	10.4	8.4	9.4	28.2	9.4
Block Total	71.6	69.6	66.4		
Grand Total				207.6	
Grand Mean					9.88

Appendix A.16a. Analysis of Variance on the Total Nodule Assessment of Mungbean as affected by Time of Spraying of Irradiated Carrageenan.

Source of Variation	df	SS	MS	F Value	Pr(> F)
Block	2	1.9657	0.9829	0.82	0.4633 ns
Treatments	6	2.2124	0.3687	0.31	0.9208 ns
Error	12	14.3676	1.1973		
Total	20	18.5457			

ns=not significant cv-11.07%

APPENDIX B- Local Agro-meteorological Data during the study

Monthly Temperature Range (˚C), Average Relative Humidity (%), and Rainfall (mm) from March 2021 to May 2021.

Month & Year	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)
	Minimum	Maximum		
March 2021	23.17	32.16	0.08	77.76
April 2021	23.06	31.12	0.05	73.98
May 2021	25.01	33.89	0.63	77.43
Total	71.24	97.17	0.76	229.17
Mean	23.75	32.39	0.253	76.39

Source: DMMMSU-PAGASA Agromet Station, Bacnotan, La Union