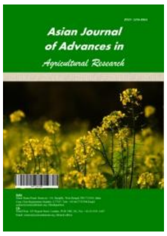

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Effect of Alkaloids Extracted from Local Lupine Plant on Growth and Yield in Pepper

Souad Abdel Latif Mohamed Al-Mursi Al-Najjar [a*]
and Al-Sayed Ahmed Fahmy Mohamed Khairy [b]

[a] Agriculture Research Department under Modified Weather Conditions, Horticultural Research Institute, Agricultural Research Center, Al Dokki, Cairo, Egypt.
[b] Department of Self-Pollinated Vegetables Research, Horticultural Research Institute, Agricultural Research Center, Al Dokki, Cairo, Egypt.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

One of the most important modern strategies to increase agricultural productivity is the recycling of wastes rich in important components that stimulate different physiological and biological activities in plants. Alkaloids removed from bitter lupine (*Lupinus termis L.*) seeds may be a good alternative natural source of industrial chemicals and may encourage plant growth and productivity as the recent global trend "aims to use natural materials to preserve the environment and avoid side effects. Due to the increased demand of sweet pepper (*Capsicum annuum L.*) for its nutritional content and high acceptance, the study goal is to improve the growth and productivity of the locally produced pepper crop by using active biological substances such as alkaloids (free of carbohydrates) extracted from bitter lupine. Bitter lupine seeds were used to extract the alkaloids free of sugar, which were subsequently dried at a temperature no higher than 50 °C. Alkaloids extract was added to each plant at concentrations (0, 500, 100, 1000, 2000) mg dw/200 ml water and its effect on vegetative evolution, output, and quality of fruit cultivar Rumi Suez were evaluated. The experiment was conducted under greenhouses in the Agricultural Research Center/Ismailia Station during the winter agricultural seasons 2019/2020 in sandy soil using three replications, Randomized Complete Block Design (R.C.B.D) and the differences among the means were tested according to Duncan's test at p≤0.05. The results showed a considerable increment in the vegetative development indicators, including plant height, main branches number, leaf area, leaves

**Corresponding author: Email: ibr23ibr23@yahoo.com;*

number, wet and dried weight of leaves and stems and leaves chlorophyll levels, in addition to productivity yield per plant, total yield, vitamin C, and phenols when treated with alkaloids extracted. It was found that the mean number of fruits, yield per plant, total yield, vitamin C content, phenols, and fruit quality increased with increasing concentrations of alkaloids used. In order to achieve the highest production and quality of pepper fruits, it is recommended to add alkaloids extracted from bitter lupine seeds, free of sugars, at a concentration of 2000 mg for each plant, dissolved in an appropriate amount of water around the plant once after two weeks of planting and then repeating it a month after planting.

Keywords: Alkaloids; lupine; growth; yield; pepper.

1. INTRODUCTION

The economic importance of sweet pepper comes because it is the third largest production next tomatoes crop and potatoes in Solanaceae family [1]. Its importance comes through its contribution to providing the human body with important energy compounds for building the human body, as every 100 gm of fresh fruits contains about 4.8% carbohydrates and 1.2% protein, in addition to some mineral salts such as potassium, calcium and iron, as well as fluorine, which protects teeth from decay [2]. Sweet pepper is the richest of all vegetables in vitamin C, as one fruit weighing 74 g can meet the necessary requirements of vitamin C (75-90 mg/day) for an adult human during one day beside a higher amount of vitamin A, B and other vitamins essential for growth [3]. The importance of the pepper crop is due to its high nutritional and health value, as pepper contains a high percentage of vitamin C and vitamin A, which helps treat stomach ulcers. It is characterized by large amounts of minerals such as sulfur, magnesium, iron, calcium, and phosphorous. It is an analgesic for pain, anti-bacterial, control with sugar level in the blood, anti-cancer, reduce the proportion of harmful triglycerides and encouraging fibers degrade in the body [4]. Nishino et al. [5] mentioned that pepper fruits have medicinal properties; it is used as a circulatory stimulant, antipyretic, an astringent in cases of diarrhea, an appetizer, and a killer of germs, as well as its role on reducing the risk of cancerous diseases. Pepper fruits contain capsaicin, which has important role in the pharmaceutical industry, as it is used in the treatment of arthritis, stomach pain, flatulence, asthma and cough, as well as it will work in the treatment of seasickness and dental pain [6]. The carotenoids in peppers include capsanthin and carotene (zeaxanthin, β-cryptoxanthin, lutein, α- and β-carotene) [7]. Cancer-preventive actions of carotenoids are linked by antioxidant properties [8].

One of the modern methods to increase agricultural production is using extracts rich in natural plant hormones, vitamins, and some macro and micronutrients for their positive effect in stimulating important physiological and biological activities in the plant that leads to an increase in plant growth, productivity and enhancing yield quality [9]. Numerous studies indicated that there are some plant extracts encouraging the characteristics of vegetative growth and yield for many plants. This may be due to the numerous natural chemical compounds found there, which vary in kind as well as different species, plant parts, stages of plant growth, and environmental conditions to which they are exposed [10].

Given the negative effects that industrial chemicals can have on humans, the environment and the organisms that live in it, the trend is to find alternatives to them from natural compounds has similar effect to what industrial chemical compounds do [11].

Sadiq et al. [12] stated that the recent global trend “aims to use natural products to preserve the environment and avoid side effects, as biologists have tended to use natural plant extracts as substitutes for industrial chemical compounds [13].

Lupine consumption has grown in recent years due to the excellent nutritional value of its flour. The flour is higher protein content and excellent nutritional functions. Pastry and bakery products, concentrated protein, and other products like yoghurt, and milk free of lactose are manufactured from lupine flour [14,15].

However, it is necessary to remove the existing alkaloids that is causing a bitter taste. Alkaloids' presence of lupine in higher doses is toxic and causes respiratory depression, a neuromuscular blockage, cyanosis, cardiac arrest, and cramps [16]. Alkaloids that reach up to 5% of lupine seeds weight contain around 8-10% of the nitrogen included in lupine seeds [17]. Bitter lupine contained between 1.68 and 2.53% alkaloids [18]. The bitter seed of lupine species had not only a high protein content but also a variety of biological activity substances such as alkaloids, raffinose, phenolic compounds, and others [19]. Lupine alkaloids are a good nitrogen source for seedlings [20]. Bitter lupine extracts improve the development and productivity of a variety of cultivated plants [21]. It is generally known that lupine extracts improve the development and productivity of numerous cultivated plants [22,23,24].

The alkaloid consist of six important alkaloids: sparteine (19%), 3-hydroxylupanine (12%), hydroxy tetrahydror hombifoline (5%), ammodendrine (3%), 5, 6-dehydrolupanine (2%), 17-oxolupanine (2%), and 19 additional minor alkaloids [25]. Many researches have shown that using lupine extract often boosts yield. Gulewicz et al. [26] shown that lupine extracts improved the development and yield of several planted plants. They discovered that extracts derived from de-bittering farmed species of alkaloid-rich lupine seeds may be used as yield enhancing agents in plant culture. Wysocki et al. [21] examined the influence of an extract (after sugar precipitation) from different lupines seeds on lettuce and tomato growth and yield. These authors' findings corroborate and demonstrate that extracts derived from several lupine species have a positive influence on the development and production of diverse plants. The differences in chemical structure of the extract, dosages, plant studied, and other factors may all influence the impact of the extracts. The biological activity of plant does not influence by extracts including sugars in their components. Przybylak et al. [24] found that applying the extract contains a low sucrose to soil in different dosages ranged between (80 to 1600 mg dw/pot) enhanced paprika fruit output and vegetative mass especially at higher doses.

Kant and Hijazi, [27] studied the effect of using bitter lupine extract on the growth and productivity of different crops as a growth regulator (spraying in amounts up to 60 kg/ha) or as a fertilizer (applications up to 250 kg/ha). Spraying with extracts as a growth regulator proved successful as the yield of winter wheat increased by 4%, corn by 8%, soybean by 18% and potato by 23%. While when the extract was used as a fertilizer when applied to the ground, the yield of winter wheat, corn and Chinese cabbage increased by up to 17, 43 and 57%, respectively. As these extracts, increase flowers number, the number of knotted fruits and the productivity of the plant.

It is well known that lupine seed extracts are high in amino acids. Using amino acids as a spray on the vegetative structure or adding to soil is improve plant growth and productivity by increasing the tissue protein content by building new types of proteins and enzymes necessary to regulate metabolic activities or activate antioxidants to make the plant more tolerant to the stresses subjected. Treating with amino acids raise the efficiency of the photosynthesis process, thus giving the best vegetative growth, increasing the number of fruits and the total yield, beside to improving the qualitative characteristics of the fruits represented by increasing the percentage of sugars, total solids, total phenols content, and antioxidants [28].

The study aimed to improve the growth and productivity of the local cultivar of pepper by alkaloids extracted from bitter lupine.

2. MATERIALS AND METHODS

2.1 Plant Materials and Treatments

The experiment achieved in the Agricultural Research Station in Ismailia, Egypt, during the 2019/2020 winter seasons in a greenhouse on sandy soil. The pH of the soil was 6.72, organic matter (1.8 g/kg), EC (1.11dSm^{-1}) at 25°C, total N (0.03 g/kg), and total phosphorus (0.02 g/kg). The cultivar of Romy Suez seedlings was cultivated on 2 January. The experiment was designed as (R.C.B.D), five treatments, three replications, fifteen experimental plots, and a 10 m^2 area for each experimental plot. The spacing among rows were 100 cm while they were 50 cm between plants. The dried extract of alkaloids at (0, 100, 500, 1000 and 2000 mg) were mixed by 200 ml water and added to the soil around each plant after two weeks of seedling and then after a month of seedling.

2.2 Preparation Alkaloid from Bitter Lupine

The seeds were extracted by ethanol 50% according to Gulewicz [29], then different sugar were precipitated from the extract by ethanol 98% [26], the supernatant liquid was condensed by rotary, and dried by oven under vacuum at temperature no exceeded about 50ºC.

2.3 Measurements

2.3.1 Vegetative characters

During the flowering stage, three plants randomly chosen from each plot to evaluate all vegetative measures like plant height, branches number, leaf area, number of leaves, shoot and leaves fresh weight, while shoot and leaves dry weight (after dried at 70°C until they reached a consistent weight). The dry weight disc technique established by Rhoads and Bloodworth [30] was used to estimate the leaf area. The chlorophyll pigments were estimated at fourth leaf and chlorophyll a, b, and carotenoids determination according to Lichtenthaler and Buschmann [31].

2.3.2 Plant yield

Plant yield was computed by adding the total harvesting for the three replicates of one treatment and dividing it on plant numbers, plot yield was measured by calculating the total fruit weight for the experimental unit, and the total yield per fed. was estimated by multiplying the number of plants per fed. by the yield of one plant.

2.3.3 Fruit quality included

2.3.3.1 Acidity

Acidity was estimated estimated by titration of sodium hydroxide (0.1 N) and the phenolphthalein as indicated by Horvitz et al. [32].

2.3.3.2 Vitamin

Ascorbic acid was calibrated against 2,6-dichlorophenolindophenol to a pink color and calculated as mg/100 g fresh weight basis as indicated by [33].

2.3.3.3 Total phenolic

The content of total phenolics was identified using as reported by Osorio-Esquivel et al. [34].

2.3.4 Statistical analysis

Data were analyses using SPSS 16 software, and means were compared using Duncan's test with a probability of 5%.

3. RESULTS AND DISCUSSIONS

3.1 Effect of Bitter Lupine Seed Alkaloids on Plant Height, Number of Branches, Leaves and Leaf Area of the Pepper Plant

Table 1 reveals that there are considerable changes in plant height between treatments over the two growing seasons. The alkaloids concentration at 2000 mg gave the maximum plant height, reaching (52 and 62 cm) during the first and the other season, whereas the control sample recorded the minimum plant height through the two seasons of cultivation (43 and 46 cm).

In terms of the number of branches, E_{2000} outperformed the other treatments and control sample by providing the most (5 and 5.4) number of branches compared to the other treatments, while the control sample which provided the fewest branches number (3 and 3.7) over the two growth seasons.

Significant changes in leaf number were noted between all treatments, with the E_{2000} treatment containing alkaloids at a concentration of 2000 mg/plant having the most leaves. During the first season, the number of leaves per plant for E_{2000} was 169, compared to 152 for the control sample, and in the second season, the number

Table 1. Effect of bitter lupine seed alkaloids on average of the plant height, number of branches, number of leaves and leaf area of pepper plant

	Plant height cm		Branch No.		Leaves No.		leaf area cm^2	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
E_0	43^e	46^e	3.0^e	3.7^d	152^e	171^e	577.3^e	644.1^e
E_{100}	45^d	47^d	3.5^d	3.8^d	158^d	176^d	614.3^d	720.6^d
E_{500}	48^c	50^c	4.0^c	4.2^c	162^c	183^c	703.6^c	842.4^c
E_{1000}	49^b	54^b	4.5^b	4.7^b	167^b	187^b	793.2^b	936.3^b
E_{2000}	52^a	62^a	5.0^a	5.4^a	169^a	193^a	854.6^a	1006.9^a

E_0: no extract (control); E_{100}: addition extract at 100 mg; E_{500}: addition extract at 500 mg; E1000: addition extract at 1000 mg; E2000: addition extract at 2000 mg

$^{a-b}$The different alphabets after means indicated significantly differences between means of treatments for each column (p< 0.05)

of leaves for E_{2000} that exceeded the first season was 193, compared to 171 for the control. Also, it is reported that the number of leaves rose throughout the two growing seasons as the concentration of the extract was raised.

The effects of the extract alkaloids on the pepper plant's leaf area during the two growing seasons were studied. It was found that the different concentrations of alkaloids resulted in significant differences in leaf area. The E_{2000} recording the highest leaf area through the two seasons (854.6 and 1006.9 cm^2) compared to the control (577.3 and 644.1 cm^2). The findings also demonstrated that leaf area increased as alkaloid concentration increased, and the increment was more significant in the second season than in the first.

This increase in vegetative growth indicators could be attributed to the hormonal effect of alkaloids, which are similar to cytokinins, gibberellins, and auxins, and then encourage plant growth, increasing nitrogen, phosphorous, and potassium absorption as they enter into many vital processes in the plant. Nitrogen and phosphorous, for example, enter the structure of many important organic molecules and contribute to the production of proteins required for cell division, as well as the development of protoplasm and other activities. Potassium activates enzymes, produces protein and energy required for cell division and elongation, and so contributes to plant height and leaf number. In addition to improving growth indicators generally, potassium is involved in the activation of numerous enzymes involved in respiration and carbon metabolism [35]. This causes an increase in photosynthesis rates and increasing the accumulation and production of dry matter in plants, which then causes an increase in growth rates, which is ultimately reflected in longer lengths, leaf count and leaf area and this similar to report by [36,37].

3.2 Effect of Bitter Lupine Seed Alkaloids on Dry and Fresh Weight of Stem and Leaves of Pepper Plant

The results in Table 2 show that all alkaloid concentrations were significantly better for stem fresh and dry weight and leaves fresh and dry weight when compared to the control. The concentration of 2000 mg/plant providing the highest average in the previous characteristics in the second season (47.1, 6.6, 41.3, and 8.1gm) when compared against (42.6, 5.9, 37.4 and 7.1gm) first season. Alkaloids gave the same enhancement for vegetative mass and dry vegetative mass on paprika with all doses ranging from 80 to 1600 mg/plant [24]. The reason for this is due to promoting effect of alkaloids on the formation of chlorophyll, which increases the photosynthesis process, which contributes to the production and accumulation of nutrients, increases the plant's dry and wet weight, and increases the plant's ability to absorb and transmit the remaining elements, such as phosphorus, more quickly and effectively. As a result of phosphorus absorption into the protoplasmic building processes, it activates enzymes and accumulates carbohydrates, increasing the plant's dry weight [38,39]. The similar trend reported by [40,41,42,43].

3.3 Effect of Bitter Lupine Seed Alkaloids on the Pigments Present in the Leaves of Pepper Plant

It is worth mentioning that the leaves are considered as the plant's food factory, due to the presence of dyes, particularly chlorophyll, which performs optical building and supplies the plant with food and energy. Table (4) demonstrates that E_{2000} was considerably superior in terms of relative chlorophyll content (a, b, c, a + b), and the rise in the second season (4.39, 3.62, 2.77, and 8.01 ppm) was more than the rise in the first season (4.12 and 3.12 and 2.25 and 7.24 ppm). Furthermore, all treatments using alkaloid extract exceeded in chlorophyll content compared with the control sample. Perhaps the positive effect of alkaloids is to increase the stimulation of chlorophyll production as a result of alkaloids' role in increasing the willingness of plants to absorb necessary nutrients such as nitrogen, phosphorous, and potassium. These nutrients play a positive role in the development of chlorophyll, which enhance the characteristics of vegetative, fruitful growth and the yield [44,45].

3.4 Effect of Bitter Lupine Seed Alkaloids on Plant Yield, Experimental Plots and Total Yield per Feddan of Pepper Crop

In terms of yield for plant or plot or feddan, the results in Table 4 revealed a substantial influence of varied concentrations of alkaloids given to the plant on plant yield, plot yield, and feddan yield. The concentration at 2000 mg/plant produced the greatest response to yield (0.66 kg/plant, 14.26 kg/plot, 5.57 ton/fed.) during the first season, while all measurements increased to (0.68 kg/plant, 13.64 kg/plot, 5.73 ton/fed.) during the second season, compared to the lowest averages of plant yield, plot and fed. yield for the control treatment (0.48 kg/plant, 10.55 kg/plot, 4.01 ton/fed.) during the first season, which amounted to (0.49 kg/plant, 10.36 kg/plot, 4.14 ton/fed.) during the second season. The positive influence of bitter lupine seed alkaloids extracts at plant yield, experimental plots and total yield in numerous cultivated plants were revealed by [23,46,24]. This is may be the effect of alkaloids of lupine extract, which operate as photosynthesis catalysts, [47], or their effect as induce nitrate reductase such as cytokinins and dihydrozeatin [48].

The reason for the E_{2000} treatment's superiority in terms of yield may be related to its effect on promoting vegetative growth such as leaf area, plant height, and chlorophyll content in the leaves (Tables 1, 3). This effect increased the carbon acting products and affected the transmission and accumulation of these products (carbohydrates and proteins) to the fruits to meet the needs of their growth and increase their size (41). In addition to positively effect on the fruits number and their weight, and then increasing the plant yield, as well as total yield as indicated by [49].

3.5 Effect of Bitter Lupine Seed Alkaloids on the Fruit Properties of Pepper Plant

Table 5 shows the decrease in acidity of pepper fruits during the two growing seasons as the concentration of alkaloids increased, with the addition of 2000 mg to a plant giving the lowest acidity (0.42 %) in the first season compared to (0.48%) in the second season. The control sample had the greatest acidity over the two growing seasons, reaching (0.66%) in the first season and (0.73) in the second.

In terms of vitamin C, its concentration increased in fruits with a high level of alkaloids applied to the plant, with the treatment E_{2000} providing the maximum content (364.63 mg/100 gm) during the second season compared to (332.90 mg/100 gm) at the first season. However, the control sample had the lowest vitamin content (265.20 mg/100 gm) in first season compared to (293.70 mg/100 gm) at second season.

Table 2. Effect of bitter lupine seed alkaloids on average of the dry and fresh weight of stem and leaves of pepper plant

	Stem fresh weight		Stem dry weight		Leaves fresh weight		Leaves dry weight	
	S1	S2	S1	S2	S1	S2	S1	S2
E_0	28.4^e	30.6^e	3.9^e	4.3^e	24.9^e	26.8^e	4.7^e	5.3^e
E_{100}	32.6^d	32.8^d	4.4^d	5.0^d	27.8^d	29.0^d	5.2^d	6.0^d
E_{500}	34.6^c	38.9^c	4.8^c	5.4^c	30.4^c	34.1^c	5.7^c	6.7^c
E_{1000}	40.1^b	43.5^b	5.6^b	6.1^b	35.3^b	38.1^b	6.7^b	7.5^b
E_{2000}	42.6^a	47.1^a	5.9^a	6.6^a	37.4^a	41.3^a	7.1^a	8.1^a

E_0: no extract (control); E_{100}: addition extract at 100 mg; E_{500}: addition extract at 500 mg; E1000: addition extract at 1000 mg; E2000: addition extract at 2000 mg

[a-b]The different alphabets after means indicated significantly differences between means of treatments for each column ($p< 0.05$)

Table 3. Effect of bitter lupine seed alkaloids on average of the leaves pigments of pepper plant

	Chlorophyll a ppm		Chlorophyll b ppm		Carotenoids ppm		Chl a+chl b	
	S1	S2	S1	S2	S1	S2	S1	S2
E_0	3.60^e	3.96^e	2.80^e	3.08^e	1.84^e	2.19^e	6.45^e	7.04^e
E_{100}	3.79^d	4.02^d	2.87^d	3.22^d	1.92^d	2.34^d	6.66^d	7.24^d
E_{500}	3.84^c	4.14^c	2.94^c	3.36^c	1.98^c	2.46^c	6.78^c	7.50^c
E_{1000}	3.99^b	4.27^b	3.02^b	3.48^b	2.13^d	2.57^b	7.01^b	7.75^b
E_{2000}	4.12^a	4.39^a	3.12^a	3.62^a	2.25^a	2.77^a	7.24^a	8.01^a

E_0: no extract (control); E_{100}: addition extract at 100 mg; E_{500}: addition extract at 500 mg; E1000: addition extract at 1000 mg; E2000: addition extract at 2000 mg

[a-b]The different alphabets after means indicated significantly differences between means of treatments for each column ($p< 0.05$)

Table 4. Effect of bitter lupine seed alkaloids on average of the plant yield, experimental plots and total yield per feddan of pepper crop

	Plant yield kg		Plot yield kg		Total yield ton/fed	
	S1	S2	S1	S2	S1	S2
E_0	0.48^e	0.49^e	10.55^e	10.36^d	4.01^e	4.14^e
E_{100}	0.50^d	0.52^d	11.07^d	10.38^d	4.23^d	4.36^d
E_{500}	0.57^c	0.57^c	12.33^c	11.45^c	4.76^c	4.81^c
E_{1000}	0.62^b	0.63^b	13.38^b	12.69^b	5.20^b	5.33^b
E_{2000}	0.66^a	0.68^a	14.26^a	13.64^a	5.57^a	5.73^a

E_0: no extract (control); E_{100}: addition extract at 100 mg; E_{500}: addition extract at 500 mg; E1000: addition extract at 1000 mg; E2000: addition extract at 2000 mg

$^{a\text{-}b}$The different alphabets after means indicated significantly differences between means of treatments for each column ($p< 0.05$)

Table 5. Effect of bitter lupine seed alkaloids on the fruit properties of pepper plant

	Acidity%		Vitamin C mg/100 g on (FW)		Total phenols mg/100 g on (FW)	
	S1	S2	S1	S2	S1	S2
E_0	0.66^e	0.73^e	265.20^e	293.70^e	28.15^e	36.40^e
E_{100}	0.60^d	0.67^d	276.27^d	318.30^d	31.42^d	39.18^d
E_{500}	0.55^c	0.64^c	288.30^c	333.50^c	33.14^c	44.53^c
E_{1000}	0.44^b	0.56^b	307.70^b	352.50^b	38.72^b	47.73^b
E_{2000}	0.42^a	0.48^a	332.90^a	364.63^a	44.62^a	51.90^a

E_0: no extract (control); E_{100}: addition extract at 100 mg; E_{500}: addition extract at 500 mg; E1000: addition extract at 1000 mg; E2000: addition extract at 2000 mg

$^{a\text{-}b}$The different alphabets after means indicated significantly differences between means of treatments for each column ($p< 0.05$)

Polyphenols are particularly noteworthy among phytochemicals due to their free radical scavenging properties and in vivo biological activity. Pepper is known to be rich in bioactive compounds like polyphenols, which are associated with reduced risks of cancer and coronary heart disease [50]. It ranges between 20 to 21 mg/100g for different pepper genotypes [51]. Phenols are among important antioxidants included in plants, and their content increased significantly in the second season of cultivation compared to the first. Also, its content was improved in the fruits of the pepper plant by increasing the concentration of the applied alkaloid extract. The addition of 2000 mg of alkaloids to the plant during the second season resulted in the largest increase of phenols with a value of 51.9 mg / 100 g compared to (44.62 g) in the first season. The antioxidant activity of the fruit can be enhanced by the phenolic components and ascorbic acid [52]. At full maturity, pepper fruit contains the highest concentration of ascorbic and phenolic compounds [30].

4. CONCLUSION

The previous research findings confirm the economic importance of reusing and recycling manufacturing waste, like resulting from the use of bitter lupine in manufacturing. It is considered alternative sources, whether for fertilizing or growth regulators, and their importance grows as a result of the fact that they are generated from natural sources instead of industrial sources that work to pollute the environment or plant. It is seen for the policy of recycling agricultural or food waste to reuse as a successful policy that has proven effective for a variety of purposes. The residues arising from bitter lupine seeds extract, which is high in alkaloids, showed to be worthy of increasing their usage in agriculture to encourage productivity and quality increases. The results proved greater branch number, plant height, leaves number and area, stem fresh weight, stem dry weight, leaves fresh weight, leaves dry weight, chlorophyll, carotenoids, plant yield, plot yield, total yield, vitamin C, total phenols with increasing the concentration of alkaloids added. To maximize pepper fruit production and quality, it is recommended to apply alkaloids extracted from bitter lupine seeds, free of sugars, at a concentration of 2000 mg per plant, dissolved in an appropriate amount of water, added around the plant once after two weeks of planting and then repeated a month later from planting.

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ETHICAL APPROVAL

As per international standards or university, the standard was written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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