Journal of Kerbala for Agricultural Sciences Issue (2), Volume (12), (2025)

Role of crushed limestone in enhancing growth, yield and yield components of flax (*Linum usitatissimum* L.)

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https://doi.org/ 10.59658/jkas.v12i2.3128

Received: Feb. 18, 2024

Accepted: Apr. 15, 2024

Published: June 20, 2025

Abstract

Flax being one of the most important industrial crops in textile after cotton, and for this reason there were a lot of researches conducted around the world. There is a little research about effect of lime on growth and yield of flax. This current experiment was done in Erbil, Kurdistan region - Iraq in the Grdarasha field. Crushed limestone used for detecting its effect on growth and yield of flax at the rates CL0 (control), CL1, CL2, CL3 as (1.5. 3.0 and 4.5 t. ha^{-1}), respectively. Thus, the results showed that when crushed limestone applied at the rate CL1 flax plant achieved the highest Number of branches plant^{-1}, number of capsules plant^{-1} and number of seeds capsule^{-1} that were (12.46 branches plant^{-1}, 48.26 capsules plant^{-1} and 8.36 seeds capsule^{-1}), respectively. On the other hand, the highest values of seed yield, biological yield and harvest index were recorded at the rate of CL3 (238.33, 880.66 and 26.90) kg. ha^{-1}, respectively in comparison to the plots with no crushed limestone application. Limestone can rearrange the soil to maximize crop growth potential. The results suggest probable for further research on the impact of crushed limestone on various crops and comparing it with other types of fertilizers or using it as a supplement to organic and inorganic fertilizers.

Keywords: Flax; plant nutrition; crushed limestone; growth and productivity improvement.

Introduction

Flax is an industrial and trade crop that plays an important part in regional strategy through both local manufacture and exporting in the world. Flax (*Linum usitatissimum* L.) from Linaceae family, which grows as an annual crop [1]. [2,3,4] describe flax as a multi-purpose crop that may provide oil from seeds and fiber from stems. The fiber extracted from stem used in textile and paper industry, while the oil from seeds can be used in cooking and medicinal purpose. Flaxseeds have gained commercial value due to their health advantages. [5] revealed that despite the flax importance, linseed production is failing to keep up with the growing demand for linseed-based products. For closing the supply and demand imbalance for flaxseed products, the optimum strategy for multi-purpose flaxseed would be to raise plant height while improving seed weight. Nutrients might be utilized as supplements to improve crop growth and yield. Thus, it is essential to enhance its growing conditions. This is accomplished by developing cultivars known for their high productivity, improving existing cultivars, or employing agricultural applications that allow the plant to exploit its genetic and physical potential at a high level of production. The availability of plant development nutrients, such as fertilizer, is critical in this respect. Chemical fertilization, or a portion of it, has recently been replaced by bio-fertilizers, which play an important role in reducing environmental pollution, maintaining biological balance, improving soil properties, root water absorption, and increasing organic matter content [6].

Lime is added to soil to improve agricultural yield by improving the availability of plant nutrients, both native and applied [7]. In addition, lime is commonly used in agriculture to treat acidic soils. Liming materials such as limestone calcium carbonate ($CaCO_3$), burned lime (CaO), and slaked lime ($Ca(OH)_2$) are commonly used to reduce plant metal absorption [8,9]. Liming improves metal immobilization and phytoavailability by increasing soil pH and Ca^{2+} concentrations [10,11]. In addition, the main direct advantages of application of limestone are a rise in pH of soil and a decrease in harmful Al and Mn concentrations. Deep lime inclusion promotes root growth, leading to enhanced production of the crops [12,13,14,15]. It was stated that the use of limestone to counteract soil acidity, with associated improvements in fertilizer-use efficiency and increases in plant yield [16,17]. [18,19] claimed that liming has many effects on crops and plants above ground. Liming has a favorable influence on plant development, leading to increase primary output. Food production is frequently regarded as the most essential provisioning function. Liming generally boosts crop yield and hence food output in arable crops such as linseed, lupins and vegetable crops. Lime's influence on nitrogen cycling (soil fertility) results in a good indirect ecosystem service consequence. [20] in a study found a substantial effect of lime on the biomass and height of bean plants. Therefore, liming induces greater yields, which are greatly dependent on crop species, type of lime, application techniques, and soil types [21]. Thus, this study aims to improve growth and yield of flax under the response of different levels of crushed limestone.

Materials and Methods

Study Site

The study was carried out in the College of Agricultural Engineering Sciences, Salahaddin University-Erbil in the Grdarasha Field. Flax was planted on December 4, 2024. Randomized Complete Block Design (RCBD) was used as a design which was accomplished of three replications. Plot size was (1 m^2), space between plots was (1 m), and also the same space was between replicates. As well as, each plot contains five rows of flax and the space between rows was (20 cm).

Materials

One variety of flax used with four levels of crushed limestone (CL); (CL0, CL1, CL2 and CL3) (0.0, 1.5, 3.0, 4.5 t ha-1), respectively.

Data Collection

At full maturity stage from each experimental stage five plants were nominated as a sample for measuring the following traits:

Growth Parameters:

Plant Height (cm)

For all five plants that selected the height measured from the base of the plant at the soil surface to the highest point of the main stem, and then the average plant height recorded expressed in (cm) [1].

Technical Stem Length (cm)

The technical stem length in flax is determined by the length of the stem from the soil surface without side branches and measured in cm [22].

Fruiting Zone Length

It is measured by the length of fruiting branches only without the main stem [1].

Yield and Yield Components Parameters:

Number of Fruiting Branches

Number of fruiting branches were measured for each plant and the averages were taken [3].

Number of Capsules Plant^{-1}

Numbers of capsules were measured for each sample and the averages were taken [1,3].

Number of Seeds Capsule^{-1}

The capsules were collected from each experimental unit of the selected plants, which were then manually rubbed and cleaned. The average number of seeds per capsule was recorded [1,3].

Seed Yield (kg ha^{-1})

After threshing, cleaning and drying seeds of flax, seed yield determined by weighting the seeds of all plants from each experimental unit [1,3].

Biological Yield (kg ha^{-1})

All plants were harvested by cutting from the soil surface for each treatment, and then the harvested plants were weighted [1,3].

Harvest Index (kg ha^{-1})

The following formula were used for calculating this parameter [23]:

$$\textbf{HI}=\frac{Seed\ yield}{Biological\ yield}\times 100$$

Statistical analysis

Growth and yield parameters were all taken at maturity stage and statistically analyzed according to the technique of analysis of variance (ANOVA) for randomized complete block design, (RCBD) using IBM SPSS Statistics program (20) the mean comparison was fulfilled according to Duncan multiple range test at the level of significant 0.05.

Soil Analysis

Table 1 displays the physical and chemical properties of the soil from the studied site. The samples were taken randomly at the depth of 0 to 30 cm from several places on the farm, which was before divided into plots. Later, the soil was air dried and sieved through a (2 mm) pore size sieve in the laboratory.

Table (1): Physicochemical properties of the soil samples from the study site.

Physicochemical Properties			
Physical properties	Sand	100.25	
	Silt	515	(g kg^{-1})
	Clay	384.75	
	Texture	Silty Clay Loma	
	pH	7.53	
	ECe	300	(µS cm^{-1})
Chemical properties	O.M.	9.6	(g kg^{-1}) (g kg^{-1}) (ppm) (mg. kg^{-1}) (ppm)
	$CaCO_3$ N (total) P (available) K (available)	306 89.17 4.67 312	

Results and Discussion

Tables 2 of ANOVA display growth and yield traits of flax plant which includes; plant height, technical stem length and fruiting zone length, while others such as; number of branches $plant^{-1}$, number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, seed yield, biological yield and harvest index were showed in the (Table 2). Thus the results showed that, PH, TL, FZ, NC and NSC none significantly influenced by different levels of limestone. Despite that, each of NB, SY, BY and HI were significantly influenced by adding crushed limestone.

Table (2): The analysis of variance (ANOVA) for the impact of crushed limestone on growth, yield and yield components parameters of flax.

Source of variation	Growth parameters			
	DF	SS	MS	F.V
PH	3	12.84	4.28	0.06^ns
TL	3	58.06	19.35	0.94^ns
FL	3	71.65	23.88	0.83^ns
Yield and yield components parameters				
NB	3	37.95	12.65	13.90*
NC	3	458.99	152.99	2.15^ns
NSC	3	0.86	0.29	0.78^ns
SY	3	61192.75	20397.58	27.82*
BY	3	301163.75	100387.92	55.36*
HI	3	630.20	210.07	40.74*

*Significant at 5%, when p-value less than 0.05 (typically ≤ 0.05). ns= none significance. DF= Degree of freedom, SS= Sum square, MS= Mean square, F.V= F. value. PH= Plant height, TL= Technical stem length, FL= Fruiting zone length, NB= Number of brunchesplant-1, NC= Number of capsulesplant-1, NSC= Number of seeds capsule-1, SY= Seed yield, BY= Biological yield and HI= Harvest index.

Plant Height (cm)

The highest plant height was recorded by the control treatment (87.53) cm as compared to other treatments (Fig. 1). According to [24] who discovered that applying surface lime considerably improved maize growth when compared to the control. But, in this current research plant height was not significantly changed may be refer to that variety which was sowed (fiber type), while several important yield parameters relative to the seed productivity were significantly improved when limestone was added to the plants. Despite that, when crushed limestone was added at the rate of (3.0) t. ha^{-1}, the plant height was improved compared to the treatments CL1 and CL3. On the other hand, could said that the impact of lime on the growth parameters was repeated in the results, rises and falls of the plant height was a proof for that purpose.

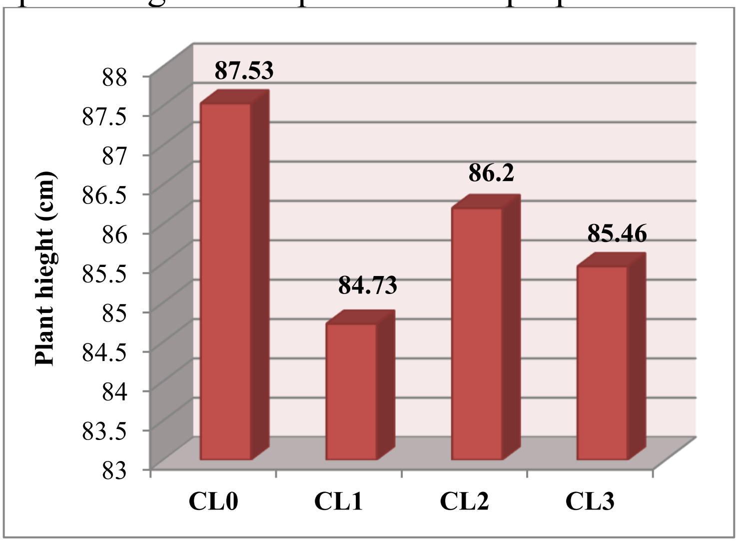

Figure (1): Effect of crushed limestone on plant height of flax.

Technical Stem Length (cm)

Technical stem length of flax approximately has the same value in which the values were (63.53 and 63.93) cm for (CL0 and CL3), respectively (Fig. 2). On the other hand, by applying crushed limestone at the level of (1.5) t. ha^{-1} technical stem length improved which was (65.06) cm. [1] demanded that technical length of stem improved by application of inorganic fertilizer and charcoal. Some relation points can be found between limestone and charcoal which are caused to improve soil such as; both of them are able to reduce heavy metal pollution by absorbing it from polluted soils, additionally by adding them pH of soil is increased and then may be potentially making situations more favorable for the microbial community.

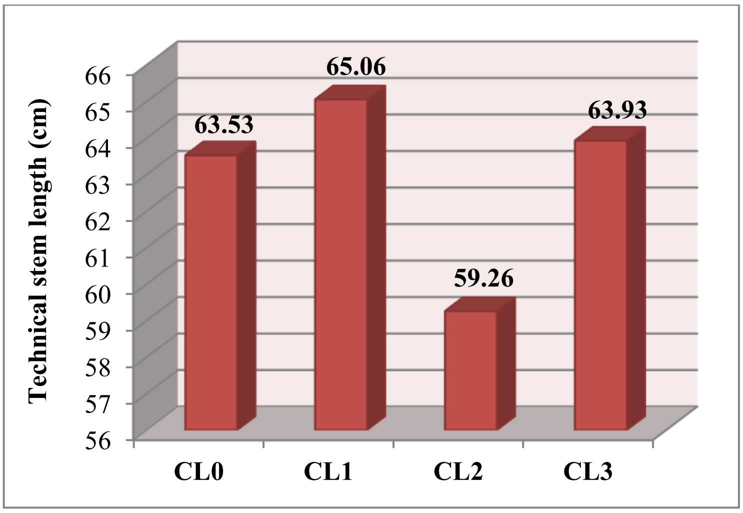

Figure (2): Effect of crushed limestone on technical stem length of flax.

Fruiting Zone Length (cm)

(Fig. 3) shows that fruiting zone length of flax changed by application of crushed limestone. The highest value was found in CL2 treatment at the rate (28.73) cm, while the lowest value was in CL1 treatment (22.4) cm. The findings of [25] showed that liming may improve crop growth rates by increasing nutrient availability and regulating soil reactions.

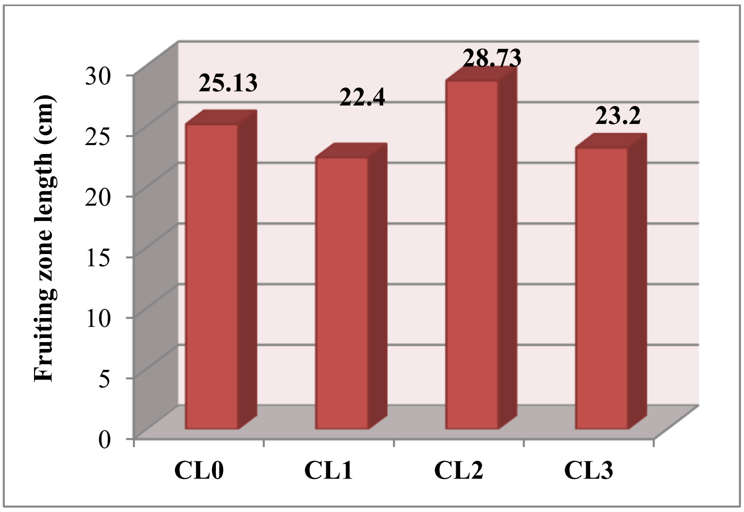

Figure (3): Effect of crushed limestone on fruiting zone length of flax.

Number of Branches Plant^{-1}

Number of branches plant^{-1} significantly increased to (12.46) branches plant^{-1}, which was by applying crushed limestone at the rate of (1.5) t. ha^{-1} (CL1) as compared to the control treatment which was (7.86) branches palnt^{-1}, (Fig. 4). Similar results were found by [26] whose informed that number of branches of soybean increased under liming condition to (5.77) branches as compared to no lime. Reaching to these results may be due to the soil physical and chemical properties, high organic matter and enhancement of microbial activity in the study site (Table 1), may all occurred by adding lime at the appropriate rate. Lime placement is effective for correcting soil acidity under no-till (NT) systems and that microbial activity and nitrification can be enhanced [27], other studies show that liming increases soil pH, enhances availability of Ca, Mg, P, N, and Mo; reduces solubility of Fe, and Mn [18], at the same time adding appropriate dose of lime in acid orchard soil could improve soil properties, soil integrated fertility, and the diversity and stability of the bacterial community [28].

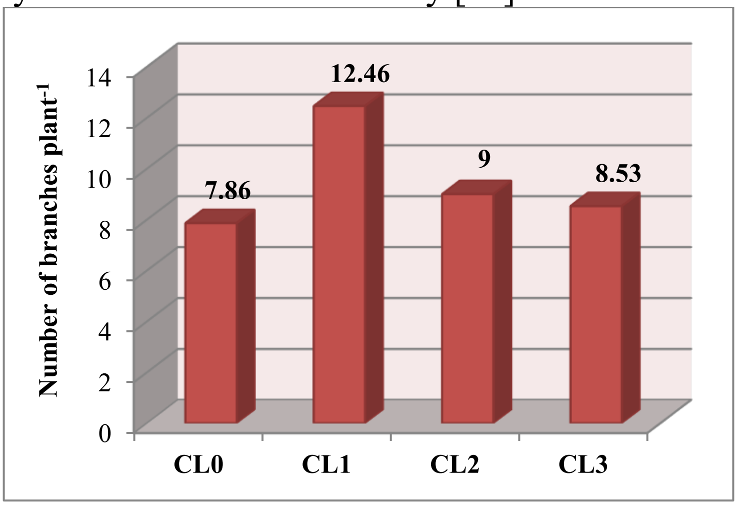

Figure (4): Effect of crushed limestone on number of branches plant^{-1} of flax.

Number of Capsules Plant^{-1}

By observing (Fig. 5) maximum and minimum numbers of capsules plant^{-1} were (48.26 and 31), which were recorded by the treatments of (CL1 and CL0), respectively. These results supported by [28] a study introduced that liming enhanced the quantity of full pods of soybean by an average of (31) % as compared to no lime. As well as, using different liming materials resulted in considerably more soybean pods per plant compared to the control. Calcium silicate had the highest pods plant^{-1} value among limning materials (63.57) [26].

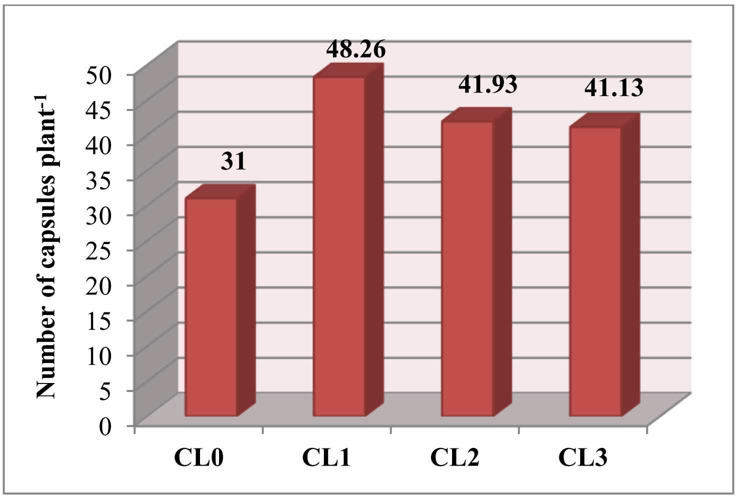

Figure (5): Effect of crushed limestone on number of capsules plant^{-1} of flax.

Number of Seeds Capsule^{-1}

Number of seeds capsule^{-1} as well not influenced by application of crushed limestone in which CL0 and CL1 has approximately the same value (8 and 8.36) seeds capsule^{-1} respectively (Fig. 6). These results in agreement with [26] were reported that the use of liming materials did not significantly affect number of seeds pod^{-1}.

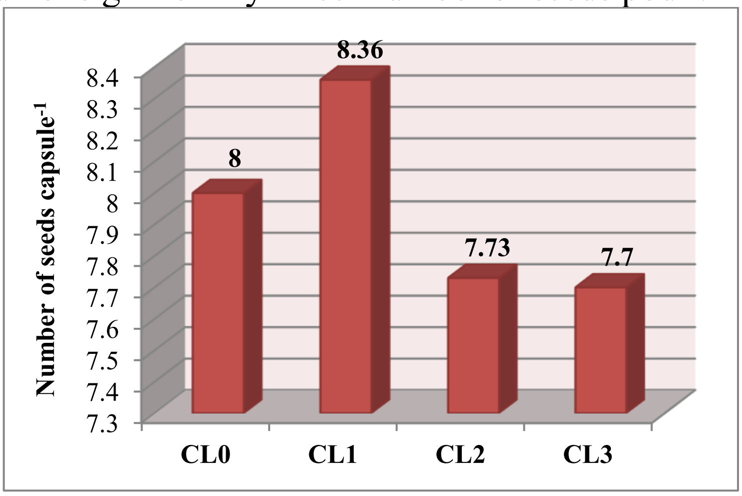

Figure (6): Effect of crushed limestone on number of seeds capsule^{-1} of flax.

Seed Yield (kg ha^{-1})

Seed yield of flax increased by increasing the applied rate of crushed limestone that the highest seed yield was (238.33) kg ha^{-1} in the treatment of CL3, while the lowest seed yield was (52.83) kg ha^{-1} in CL0 (control) (Fig. 7). These results in agreement with [29] in an experiment used three types of lime such as micronized liming material, dolomitic limestone, granulated micronized calcite and granulated micronized dolomite in different rates. The results of that study revealed that regardless of the type or dose of limestone, seed yield of crops wheat, maize, soybean and black oat was relatively increased. [30] in their study found that using a variety of mineral fertilizers, manure, and liming resulted in high flax fiber yields (18.5-18.9) hwt ha^{-1} in seeds (7.9-8.3) hwt ha^{-1}. [31] also observed comparable findings. Increased seed yield may be attributed to increased pod numbers, seeds per pod, and seed weight. According to [32] who investigated that lint yield of cotton enhanced by application of lime.

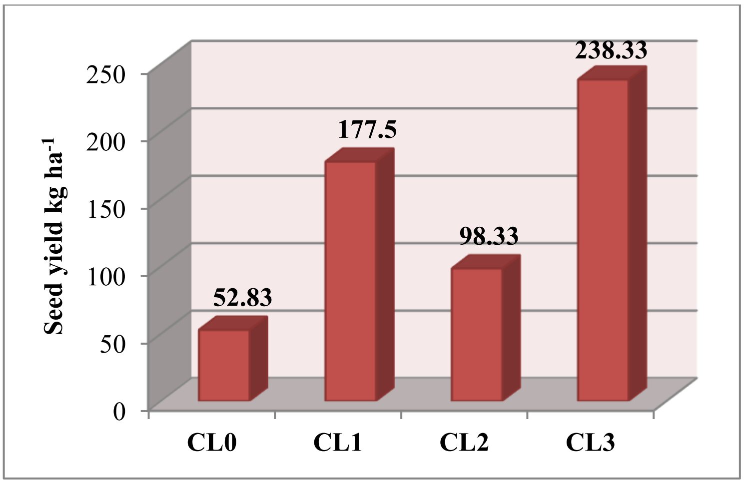

Figure (7): Effect of crushed limestone on seed yield of flax.

Biological Yield (kg ha^{-1})

Increasing the level of crushed limestone positively improved biological yield of flax, as can be seen in (Fig. 8). CL3 recorded (880.66) kg ha^{-1} as compared to control treatment which was (755.5) kg ha^{-1}. These results in contrast with [30] that demanded liming increased straw yield of flax by (1.4-5.5) hwt ha^{-1} compared to non-liming plots. The highest dry-matter production was observed when lime was incorporated to the soil [33]. Biological yield of wheat significantly increased by application of lime in compression to non-limed traits [34].

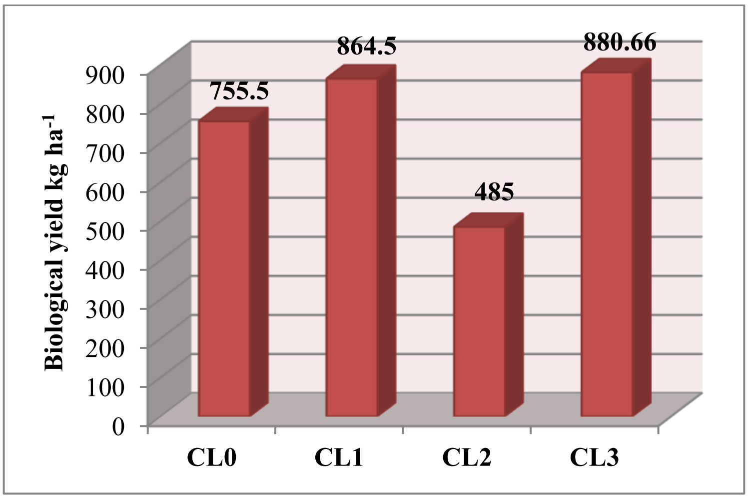

Figure (8): Effect of crushed limestone on biological yield of flax.

Harvest Index (kg ha^{-1})

Amazing differences were found of harvest index between untreated plots compared to treated plots. Maximum and minimum harvest index were (26.9 and 7) kg ha^{-1} detected by the treatments (CL3 and CL0), respectively (Fig 9). These outcomes show the impact of crushed limestone on enhancing yield and its productivity of flax plant. [34] also reached to the results those treatments with liming increased harvest index of wheat as compared to other treatments with no liming. Using environmentally friendly, biologically active compounds can improve flax cultivation's economic efficiency by increasing production [30]. Increased liming concentration resulted in a higher shoot/root dry weight ratio for cotton [35]. Thought, [36] discovered that plowing and harrowing lime improved crop dry mass more than surface application in no tillage systems.

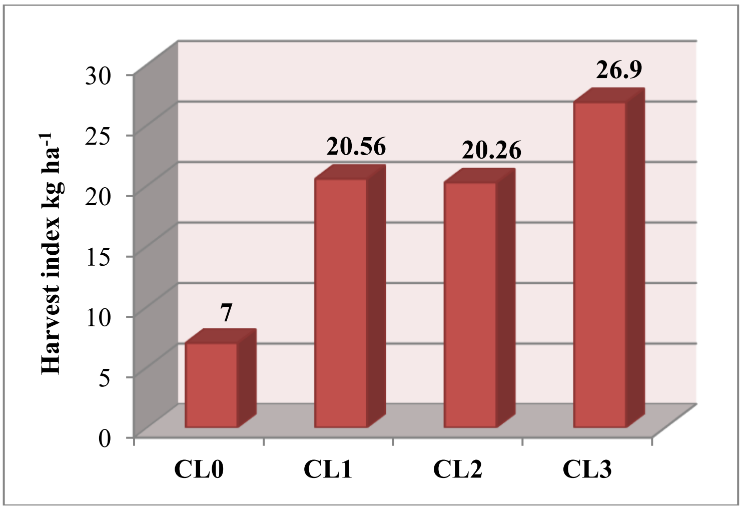

Figure (9): Effect of crushed limestone on harvest index of flax.

Generally, the results of this research approved that crushed limestone application influenced various growth, yield and yield components of flax. Especially when crushed limestone applied at the rate (1.5) t ha^{-1} which was increased number of branches plant^{-1}, number of capsules palnt^{-1} and number of seeds capsule^{-1}. On the other hand, the optimizing application of crushed limestone to (4.5) t ha^{-1} improved plant height, technical stem length, seed yield, biological yield and harvest index as compared to the control treatment. Thereby, these findings provide valuable insights for cultivation of flax and enhancing its yield and yield components which is under condition of limestone application and likewise for other crops may be true.

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