J. of Plant Production, Mansoura Univ., Vol. 16 (6):291 -297, 2025

Journal of Plant Production

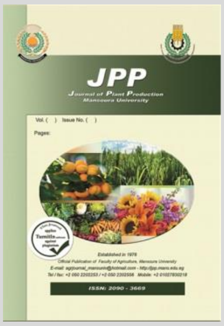
Journal homepage & Available online at: www.jpp.journals.ekb.eg

Optimizing Lettuce Productivity using Chicken Manure under Different Planting Densities and Varying Nitrogen Levels

Albaba, H. B. [1]; Y. F. E. IMRYED[2*]; A. M. Abouzaytonh[3] and O. S. Belgasm[4]

[1]Plant Production Department, Agriculture Faculty/ University of Kufra,, Libya
[2] Department of Plant Production, Faculty of Agriculture, Benghazi University, Libya
[3] Department of Botany, Faculty of Science, University of Kufra,, Libya
[4] Department of Horticulture. Faculty of Agriculture. Omar AL-Mukhtar University, El Beida-Libya

Cross Mark



ABSTRACT

To study the potential of organic fertilizers as partial substitutes for mineral nitrogen to enhance lettuce productivity and minimizing excessive nitrogen use and promoting sustainable agricultural practice, a field experiment was implemented during two consecutive winter seasons of 2016/2017 and 2017/2018. Lettuce was used as an experimental plant. The experiment was laid out in a split-split plot design, as the main plots were assigned to four levels of organic fertilizer (Chicken manure ChM) at rates of 0, 10, 20, and 30 ton ha^{-1}. The sub-plots received four nitrogen fertilizer levels (urea, 46% N) at rates of 0, 90, 180, and 270 kg N ha^{-1}, while the sub-sub plots were designated for two planting distances: 20 × 60 cm and 40 × 60 cm. The measured parameters included total fresh and dry yield, total head yield, head weight and diameter and NPK contents. The results showed that the most superior treatment combination across both seasons was the application of 30 tons ha^{-1} ChM combined with 270 kg N ha^{-1} and the closer planting distance, which led to the highest total and marketable yields. It is also noteworthy that the treatment involving 30 tons ha^{-1} of chicken manure combined with 180 kg N ha^{-1} and the closer planting distance (20×60 cm) produced results that were not significantly different from those obtained with the treatment that received 270 kg N ha^{-1} without any organic manure under the same planting distance. This finding highlights the partial substitution role of organic manure in supplying nitrogen.

Keywords: Lettuce, chicken manure, sustainable agriculture

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is one of the most widely cultivated leafy vegetables worldwide, valued for its high nutritional content, rapid growth cycle, and economic importance. The increasing demand for fresh produce has led to intensified production systems, which require optimal management of fertilization and planting density to ensure high yield and quality (Shatilov *et al.* 2019). However, excessive reliance on mineral fertilizers alone may lead to soil degradation, nutrient leaching, and negative environmental impacts. Thus, integrating organic fertilizers such as ChM with mineral fertilizers has emerged as a sustainable approach to enhance soil fertility, promote plant growth, and improve crop productivity (Doklega & Imryed, 2020).

Nitrogen, an essential macronutrient, plays a crucial role in chlorophyll synthesis, protein formation, and vegetative development. Nonetheless, its efficient utilization by lettuce plants can be significantly influenced by the form and amount applied, as well as the growing conditions (Raina& Mazahar, 2022). In this context, urea is a widely used nitrogen source due to its high nitrogen content (46%). However, its effectiveness can be enhanced when combined with organic amendments that improve soil structure and microbial activity (Witte, 2011).

In addition to fertilization practices, planting density is a key agronomic factor that affects light interception, nutrient competition, and overall crop performance. Optimizing plant spacing is particularly important for leafy vegetables like lettuce, where head size and marketable yield are directly related to space availability (Mengistu *et al.* 2021).

Given this background, the present study was conducted aiming to investigate the interactive effects of different levels of organic and nitrogen fertilization, as well as two planting densities, on the yield of lettuce.

MATERIALS AND METHODS

Experimental site and duration:

This field study was conducted at the Experimental Farm of the Department of Horticulture, Faculty of Agriculture, Omar Al-Mukhtar University, Al-Bayda, Libya, during two consecutive winter seasons of 2016/2017 and 2017/2018. The site is located in a Mediterranean climatic region characterized by mild winters and moderate rainfall.

Experimental design and treatments:

The experiment was laid out in a split-split plot design with three replications. The main plots were assigned to four levels of organic fertilizer (Chicken manure ChM) at rates of 0, 10, 20, and 30 ton ha^{-1}. The sub-plots received four nitrogen fertilizer levels (urea, 46% N) at rates of 0, 90, 180, and 270 kg N ha^{-1}. The sub-sub plots were designated for two planting distances: 20 × 60 cm and 40 × 60 cm. Each experimental unit consisted of a bed accommodating lettuce transplants according to the respective spacing treatment.

Soil and ChM analysis:

Prior to the initiation of the field experiment in both seasons, soil samples from the experimental site were

* **Corresponding author.**
E-mail address: yousi.imriad@uob.edu.ly
DOI:10.21608/jpp.2025.390235.1468

collected and analyzed to determine their physicochemical properties. The characteristics of the ChM used were also analyzed. All analyses were carried out following the standard procedures described by Tandon (2005). The results of the soil and ChM analysis are presented in Tables 1 and 2, respectively.

Table 1. Initial soil properties during both studied seasons

Measurements		Season of 2016/17	Season of 2017/18
Particle	Clay	31.15	34.60
Size	Silt	53.60	51.15
distribution, %	sand	15.25	14.25
Organic Matter,%		2.45	2.30
Soil pH		7.96	7.87
EC, dSm^{-1}		1.30	1.36
Total Nitrogen, %		0.23	0.21
P,$mgkg^{-1}$		118	115

Table 2. Chicken manure characteristics before transplanting during both studied seasons

Properties	Season of 2016/17	Season of 2017/18
Total phosphorous,%	1.55	1.32
Total potassium,%	1.09	71.0
Total nitrogen ,%	3.65	3.745
pH	7.15	7.30
EC, dSm^{-1}	4.20	4.30
Organic matter,%	68	70

Seedling production and transplanting:

Lettuce seedlings (cv. Balmoral) were raised in plastic Speedling trays containing 209 cells (11 × 19 cells per tray), with each cell measuring 3 × 3 × 6 cm. The growing medium consisted of peat moss and loam soil mixed in a 1:3 volume ratio. Calcium carbonate was added to adjust the pH, and antifungal agents were incorporated to minimize fungal infections. The mixture was well homogenized, moistened with water, and incubated for two days before filling the trays. Seeds were sown mechanically, placing one seed per cell during October of both seasons. The trays were initially covered with plastic sheets and stacked for three days to promote uniform germination. Afterward, the trays were placed on wire mesh benches in a protected nursery environment, and standard nursery practices were followed until transplanting. No fertilizers were applied during the nursery period, either as soil amendments or foliar sprays.Once the seedlings reached transplanting size (approximately five weeks after sowing), they underwent a hardening-off period involving water withholding for three days and gradual exposure to ambient field conditions to ensure successful establishment post-transplanting.

Field transplanting and crop management:

Transplanting was carried out in December for both seasons. One seedling was planted per point according to the designated spacing (20 × 60 cm or 40 × 60 cm). All recommended agronomic practices for lettuce production were followed. Before transplanting, single superphosphate (15.5% P_2O_5) was applied at 400 kg ha^{-1}, and potassium sulfate (48% K_2O) at 250 kg ha^{-1}. The phosphorus fertilizer was incorporated into the soil one week before transplanting, while potassium was applied in two equal splits: one before transplanting and the second one week after transplanting. Nitrogen fertilizer (urea, 46% N) was applied in two equal doses according to the treatment levels; first dose one week after transplanting and the second dose one month later. Drip irrigation was used throughout the experiment to maintain optimal soil moisture. A plant protection program was implemented according to the recommended practices for commercial lettuce production.

Measurements:

At harvest, the following parameters were recorded from each experimental unit; Total fresh yield (ton ha^{-1}), total dry yield (ton ha^{-1}), total head yield (ton ha^{-1}), head fresh weight (g), head diameter (cm). Plant samples were digested using a mixture of perchloric and sulfuric acid in a ratio of 1:1, and then nitrogen, phosphorus and potassium were determined according to Ryan *et al.* (2001). Also, growth criteria *i.e.,* plant fresh weight (g), fresh weight of uncurled leaves (g), plant height (cm), No. of uncurled leaves, plant dry weight (g) were measured.

Statistical analysis:

The collected data were statistically analyzed for both growing seasons using the MSTAT-C statistical software. Analysis of variance (ANOVA) was performed according to the method described by Snedecor and Cochran (1967). Treatment means were separated using the Least Significant Difference (LSD) test at the 5% level of significance.

RESULTS AND DISCUSSION

1. Head yield and its components

The data presented in Tables 3 and 4 demonstrate the effect of the triple interaction between chicken manure (ChM) application rates (0, 10, 20, and 30 tons ha^{-1}), nitrogen fertilization levels (0, 90, 180, and 270 kg N ha^{-1}), and planting distances (20×60 cm and 40×60 cm) on lettuce performance across two consecutive seasons (2016/17 and 2017/18). The measured parameters included total fresh yield (ton ha^{-1}), total dry yield (ton ha^{-1}), total head yield (ton ha^{-1}), head fresh weight (g), and head diameter (cm).

In both seasons, a clear trend was observed whereby increasing both organic and inorganic fertilization, especially under closer planting distance (20×60 cm), significantly enhanced all yield parameters. The most superior treatment combination across both seasons was the application of 30 tons ha^{-1} ChM combined with 270 kg N ha^{-1} and the closer planting distance, which led to the highest total and marketable yields and superior morphological characteristics. In other words, it can be said that the the values of all aforementioned traits increased as the level of ChM and urea increased and the best planting distance was 20×60 (cm).

The results from both seasons consistently reveal that the triple interaction significantly influenced lettuce yield and its components. The highest productivity in terms of total fresh yield, dry yield, and head weight was recorded when 30 tons ha^{-1} of ChM was combined with 270 kg N ha^{-1} and a closer spacing of 20×60 cm. This can be attributed to the synergistic effects of organic and inorganic nitrogen sources that improve soil fertility, microbial activity, and nutrient availability throughout the growing season. The organic matter from ChM enhances water-holding capacity and cation exchange, while the applied mineral nitrogen ensures readily available N for immediate plant uptake.

The closer planting distance (20×60 cm) also played a crucial role in maximizing yield per unit area, likely due to increased plant density and enhanced canopy coverage, which leads to more effective light interception and photosynthesis. Although wider spacing (40×60 cm) promoted slightly better individual head weights and diameters in some treatments, the yield per hectare was always lower due to fewer plants.

Table 3. Effect of the triple interaction between ChM rates, nitrogen levels and planting distances on lettuce yield and its components during the growing season of 2016/17

Parameters Treatments			Total fresh yield, ton ha^{-1}	Total dry yield, ton ha^{-1}	Total head yield, ton ha^{-1}	Head fresh weight, g	Head diameter, cm
Control (without organic fertilizer)	Control (without N)	Planting distance of 20×60 cm	34.569 m	0.757 q	26.572 kl	319 r	4.1 t
		Planting distance of 40×60cm	21.5480 t	0.471 v	16.626 r	399.6 q	4.433 s
	90 kg N ha^{-1}	Planting distance of 20×60 cm	45.6480 j	0.999 no	35.125 hi	421.6 opq	5.933 o
		Planting distance of 40×60cm	23.781 st	0.520 tuv	18.789 pqr	451.6 mno	6.133 o
	180 kg N ha^{-1}	Planting distance of 20×60 cm	48.175 hi	1.055 mn	38.956 fg	467.6 klm	7.583 k
		Planting distance of 40×60cm	26.388 gr	0.578 st	20.536 nop	493.6 ijk	7.733 jk
	270 kg N ha^{-1}	Planting distance of 20×60 cm	57.116 e	2.844 b	45.954 d	551.6 f	8.433 h
		Planting distance of 40×60cm	31.075 no	0.680 qr	25.902 l	622.6 d	9.033 f
Addition of ChM at rate of 10 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	41.2890 k	0.941 op	33.903 i	407 pq	4.566 s
		Planting distance of 40×60cm	21.4790 t	0.489 uv	18.012 qr	433 nop	4.823 r
	90 kg N ha^{-1}	Planting distance of 20×60 cm	49.452 ghi	1.127 lm	37.263 gh	447.3 mno	6.666 n
		Planting distance of 40×60cm	24.5990 rs	0.561 stu	20.092 nopq	483 jkl	6.806 mn
	180 kg N ha^{-1}	Planting distance of 20×60 cm	53.2010 f	1.213 k	43.399 e	521 ghi	7.833 j
		Planting distance of 40×60cm	27.206 pq	0.620 rs	22.436 mn	539.3 fg	7.933 ij
	270 kg N ha^{-1}	Planting distance of 20×60 cm	64.280 c	1.465 i	52.729 b	633 cd	9.2 ef
		Planting distance of 40×60cm	32.545 mn	0.742 q	27.539 jkl	662 bc	9.333 de
Addition of ChM at rate of 20 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	47.620 ij	1.676 h	33.847 i	406.3 pq	4.883 r
		Planting distance of 40×60cm	24.904 qrs	0.876 p	17.874 qr	429.6 opq	5.266 q
	90 kg N ha^{-1}	Planting distance of 20×60 cm	50.146 gh	1.765 g	38.817 g	466 klm	6.866 mn
		Planting distance of 40×60cm	26.180 qrs	0.921 op	20.606 nop	495.3 ijk	6.9 m
	180 kg N ha^{-1}	Planting distance of 20×60 cm	53.423 f	1.880 f	42.011 e	504.3 hij	8.133 i
		Planting distance of 40×60cm	29.633 op	1.043 n	22.103 mno	531.3 fgh	8.4 h
	270 kg N ha^{-1}	Planting distance of 20×60 cm	67.139 b	2.363 e	54.117 b	649.6 cd	9.533 cd
		Planting distance of 40×60cm	34.015 m	1.197 kl	28.676 jk	689.3 ab	9.566 c
Addition of ChM at rate of 30 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	49.258 ghi	2.453 d	38.568 g	463 lmn	5.566 p
		Planting distance of 40×60cm	25.598 qrs	1.274 jk	19.801 opq	476 jklm	5.550 p
	90 kg N ha^{-1}	Planting distance of 20×60 cm	51.673 fg	2.573 c	41.261 ef	495.3 ijk	7.166 l
		Planting distance of 40×60cm	27.220 pq	1.355 j	21.937 mno	527.3 fgh	7.3 l
	180 kg N ha^{-1}	Planting distance of 20×60 cm	60.6140 d	1.327 j	49.036 c	588.6 e	9.133 ef
		Planting distance of 40×60cm	30.784 no	1.533 i	23.088 m	555 f	8.75 g
	270 kg N ha^{-1}	Planting distance of 20×60 cm	72.415 a	3.606 a	58.365 a	700.6 a	9.816 ab
		Planting distance of 40×60cm	38.327 l	1.908 f	29.660 j	713 a	10.116 a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 4. Effect of the triple interaction between ChM rates, nitrogen levels and planting distances on lettuce yield and its components during the growing season of 2017/18

Parameters Treatments			Total fresh yield, ton ha^{-1}	Total dry yield, ton ha^{-1}	Total head yield, ton ha^{-1}	Head fresh weight, g	Head diameter, cm
Control (without organic fertilizer)	Control (without N)	Planting distance of 20×60 cm	42.705k	1.119o	32.681de	392.33ef	4.43r
		Planting distance of 40×60cm	21.326s	0.558x	16.279g	391.33ef	4.7q
	90 kg N ha^{-1}	Planting distance of 20×60 cm	43.816hij	1.148mn	32.792de	392.66ef	6.16m
		Planting distance of 40×60cm	22.034rs	0.577x	16.390g	392.33ef	6.43l
	180 kg N ha^{-1}	Planting distance of 20×60 cm	46.453ef	1.217l	32.931cde	395.33cf	8.23h
		Planting distance of 40×60cm	23.379op	0.612w	16.418g	396.66cf	8.2h
	270 kg N ha^{-1}	Planting distance of 20×60 cm	48.286d	2.569b	34.375b	398.66cf	9.53e
		Planting distance of 40×60cm	24.474mn	0.641v	16.348g	395.33cf	10.4c
Addition of ChM at rate of 10 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	42.899jk	1.282k	32.709de	393.66ef	4.7q
		Planting distance of 40×60cm	21.479rs	0.642v	16.321g	394d-f	4.8pq
	90 kg N ha^{-1}	Planting distance of 20×60 cm	44.26hi	1.323i	32.459de	389.66ef	6.86k
		Planting distance of 40×60cm	22.27qr	0.665u	16.127g	387.66f	7.16j
	180 kg N ha^{-1}	Planting distance of 20×60 cm	47.286e	1.414h	32.292e	398c-f	8.26h
		Planting distance of 40×60cm	23.795nop	0.711t	16.168g	398.33c-f	8.73g
	270 kg N ha^{-1}	Planting distance of 20×60 cm	49.508c	1.480g	32.737de	396c-f	10.4c
		Planting distance of 40×60cm	24.876m	0.744s	16.390g	395.33c-f	10.7b
Addition of ChM at rate of 20 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	43.371ijk	1.826f	32.931cde	395.33c-f	4.93p
		Planting distance of 40×60cm	21.645rs	0.911r	16.501g	394.66d-f	5.33o
	90 kg N ha^{-1}	Planting distance of 20×60 cm	44.676gh	0.939q	33.153cde	387.66f	7.2j
		Planting distance of 40×60cm	22.394qr	0.943q	16.570g	388.66ef	7.36j
	180 kg N ha^{-1}	Planting distance of 20×60 cm	48.480d	2.041e	33.819bc	406bc	9.23f
		Planting distance of 40×60cm	24.017mno	1.011p	16.598g	399c-e	9.4ef
	270 kg N ha^{-1}	Planting distance of 20×60 cm	51.313b	1.129no	33.209cd	412.66b	10.66b
		Planting distance of 40×60cm	27.539l	1.159m	16.529g	450.66a	10.86ab
Addition of ChM at rate of 30 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	43.510ijk	2.314d	33.736bc	394d-f	5.76n
		Planting distance of 40×60cm	21.895rs	1.164m	16.446g	393ef	5.86n
	90 kg N ha^{-1}	Planting distance of 20×60 cm	45.565fg	2.424c	32.987cde	393ef	7.76i
		Planting distance of 40×60cm	23.005pq	1.223l	16.446g	394d-f	7.9i
	180 kg N ha^{-1}	Planting distance of 20×60 cm	49.758c	1.303j	32.820de	405b-d	10.33c
		Planting distance of 40×60cm	24.155mno	1.285jk	18.748f	397.33c-f	9.96d
	270 kg N ha^{-1}	Planting distance of 20×60 cm	55.561a	2.955a	37.568a	451a	10.93a
		Planting distance of 40×60cm	27.858l	1.482g	18.692f	449.33a	11a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Interestingly, lettuce grown without nitrogen or organic fertilizer (control treatments) showed the poorest performance, underscoring the importance of nutrient supplementation for optimum productivity. Even the moderate application of 90 kg N ha⁻¹ or 10 t ha⁻¹ ChM alone led to intermediate responses, indicating a dose-dependent effect of both fertilizers.

It is also noteworthy that the treatment involving 30 tons ha⁻¹ of chicken manure combined with 180 kg N ha⁻¹ and the closer planting distance (20×60 cm) produced results that were not significantly different from those obtained with the treatment that received 270 kg N ha⁻¹ without any organic manure under the same planting distance. This finding highlights the partial substitution role of organic manure in supplying nitrogen and improving lettuce performance, even when the mineral nitrogen dose is reduced. The composted chicken manure likely enhanced nitrogen use efficiency through improved soil structure, increased microbial activity, and reduced nutrient losses, thereby compensating for the lower mineral N input. This emphasizes the potential of integrating organic amendments as a sustainable and environmentally friendly strategy to reduce reliance on high chemical fertilizer inputs.

Between the two seasons, the trends were consistent; however, the 2017/18 season showed slightly improved results in dry matter accumulation, possibly due to better climatic conditions or improved soil residual fertility from the previous season's organic amendments. The superior performance observed under combined high N and ChM treatments can be explained by the complementary roles of organic and inorganic nutrition. Organic amendments improve soil structure, stimulate microbial activity, and release nutrients gradually, whereas mineral fertilizers provide quick-release forms that satisfy immediate plant demands. The combination likely optimized nitrogen use efficiency (NUE) and reduced leaching losses.In terms of plant physiology, nitrogen is critical for chlorophyll synthesis, protein formation, and cell division, which are vital for leaf expansion and head formation in lettuce. Furthermore, higher N levels likely delayed senescence, enabling longer photosynthetic activity and biomass accumulation. The organic matter from ChM also improves root growth and nutrient uptake, thereby reinforcing the effects of nitrogen fertilization. The spacing effect is also notable; closer spacing increased total yield due to higher plant populations, whereas wider spacing allowed for larger individual heads but reduced total output. This trade-off highlights the importance of balancing plant density with resource availability and crop objectives. These findings are consistent with several previous studies such as Doklega & Imryed, (2020); Mengistu *et al.* (2021).

2.Leaf chemical constituents

Tables 5 and 6 illustrate the interactive effect of composted chicken manure (ChM) rates, nitrogen fertilizer levels, and planting distances on the chemical composition of lettuce leaves during the 2016/17 and 2017/18 growing seasons, respectively. The data indicate that the application of higher ChM rates, combined with increasing nitrogen levels and wider planting distances (40×60 cm), led to noticeable improvements in the leaf contents of nitrogen, phosphorus, and potassium.

Table 5. Effect of the triple interaction between ChM rates, nitrogen levels and planting distances on leaf chemical constituents of lettuce during the growing season of 2016/17

Parameters / Treatments			Nitrogen, %	Phosphorus, %	Potassium, %
Control (without organic fertilizer)	Control (without N)	Planting distance of 20×60 cm	0.753n	0.088n	1.143r
		Planting distance of 40×60cm	0.773mn	0.089n	1.113r
	90 kg N ha^{-1}	Planting distance of 20×60 cm	0.906kn	0.143cf	1.313p
		Planting distance of 40×60cm	1.013hk	0.111jl	1.223q
	180 kg N ha^{-1}	Planting distance of 20×60 cm	0.35o	0.125gj	1.496gh
		Planting distance of 40×60cm	1.093gi	0.130fi	1.523fg
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.12fi	0.138dg	1.573ce
		Planting distance of 40×60cm	1.176dh	0.146ce	1.6ad
Addition Of ChM at rate of 10 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	0.843ln	0.096mn	1.21q
		Planting distance of 40×60cm	0.906kn	0.109km	1.286p
	90 kg N ha^{-1}	Planting distance of 20×60 cm	0.956in	0.112jl	1.296p
		Planting distance of 40×60cm	1.156dh	0.104lm	1.316op
	180 kg N ha^{-1}	Planting distance of 20×60 cm	1.106gi	0.134ef	1.39n
		Planting distance of 40×60cm	1.21dg	0.139dg	1.43jm
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.206dg	0.143cf	1.593bd
		Planting distance of 40×60cm	1.296ce	0.150bd	1.603ac
Addition of ChM at rate of 20 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	0.923jm	0.118il	1.35o
		Planting distance of 40×60cm	1.11gi	0.127gi	1.403mn
	90 kg N ha^{-1}	Planting distance of 20×60 cm	1.076gj	0.111jl	1.44jl
		Planting distance of 40×60cm	1.203dg	0.125gi	1.46ij
	180 kg N ha^{-1}	Planting distance of 20×60 cm	1.15eh	0.138dg	1.53fg
		Planting distance of 40×60cm	1.296ce	0.153bc	1.566de
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.28cf	0.151bd	1.6ad
		Planting distance of 40×60cm	1.413ac	0.154bc	1.61ab
Addition of ChM at rate of 30 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	1.066gk	0.122hk	1.406ln
		Planting distance of 40×60cm	1.15eh	0.131fi	1.423kn
	90 kg N ha^{-1}	Planting distance of 20×60 cm	1.226dg	0.112jl	1.45ik
		Planting distance of 40×60cm	1.396ac	0.121hk	1.48hi
	180 kg N ha^{-1}	Planting distance of 20×60 cm	1.323bd	0.150bd	1.546ef
		Planting distance of 40×60cm	1.473ab	0.144cf	1.566de
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.413ac	0.161b	1.626de
		Planting distance of 40×60cm	1.533a	0.183a	1.633a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 6. Effect of the triple interaction between ChM rates, nitrogen levels and planting distances on leaf chemical constituents of lettuce during the growing season of 2017/18

Parameters /Treatments			Nitrogen, %	Phosphorus, %	Potassium, %
Control (without organic fertilizer)	Control (without N)	Planting distance of 20×60 cm	0.753n	0.088n	1.143r
		Planting distance of 40×60cm	0.773mn	0.089n	1.113r
	90 kg N ha^{-1}	Planting distance of 20×60 cm	0.906kn	0.143cf	1.313p
		Planting distance of 40×60cm	1.013hk	0.111jl	1.223q
	180 kg N ha^{-1}	Planting distance of 20×60 cm	0.35o	0.125gj	1.496gh
		Planting distance of 40×60cm	1.093gi	0.130fi	1.523fg
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.12fi	0.138dg	1.573ce
		Planting distance of 40×60cm	1.176dh	0.146ce	1.6ad
Addition of ChM at rate of 10 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	0.843ln	0.096mn	1.21q
		Planting distance of 40×60cm	0.906kn	0.109k-m	1.286p
	90 kg N ha^{-1}	Planting distance of 20×60 cm	0.956il	0.112jl	1.296p
		Planting distance of 40×60cm	1.156dh	0.104lm	1.316op
	180 kg N ha^{-1}	Planting distance of 20×60 cm	1.106gi	0.134eh	1.39n
		Planting distance of 40×60cm	1.21dg	0.139dg	1.43jm
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.206dg	0.143cf	1.593bd
		Planting distance of 40×60cm	1.296ce	0.150bd	1.603ac
Addition of ChM at rate of 20 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	0.923m	0.118jl	1.350
		Planting distance of 40×60cm	1.11gi	0.127gi	1.403mn
	90 kg N ha^{-1}	Planting distance of 20×60 cm	1.076gi	0.111jl	1.44jl
		Planting distance of 40×60cm	1.203dg	0.125gj	1.46ij
	180 kg N ha^{-1}	Planting distance of 20×60 cm	1.15eh	0.138dg	1.53fg
		Planting distance of 40×60cm	1.296ce	0.153bc	1.566de
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.28cf	0.151bd	1.6ad
		Planting distance of 40×60cm	1.413ac	0.154bc	1.61ab
Addition of ChM at rate of 30 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	1.066gk	0.122hk	1.406ln
		Planting distance of 40×60cm	1.15eh	0.131fi	1.423kn
	90 kg N ha^{-1}	Planting distance of 20×60 cm	1.226dg	0.112jl	1.45ik
		Planting distance of 40×60cm	1.396ac	0.121hk	1.48hi
	180 kg N ha^{-1}	Planting distance of 20×60 cm	1.323bd	0.150bd	1.546ef
		Planting distance of 40×60cm	1.473ab	0.144cf	1.566de
	270 kg N ha^{-1}	Planting distance of 20×60 cm	1.413ac	0.161b	1.626ab
		Planting distance of 40×60cm	1.533a	0.183a	1.633a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

In contrast, the lowest values were observed in treatments without organic or nitrogen fertilization, regardless of planting distance. The observed improvement in leaf chemical composition, particularly under the combined application of 30 ton ha⁻¹ of ChM and 270 kg N ha⁻¹ with 40×60 cm spacing, can be attributed to that ChM may have improved soil fertility by increasing organic matter content, microbial activity, and cation exchange capacity. This promotes better retention and gradual release of nutrients, especially nitrogen, phosphorus, and potassium. The combination of organic and mineral nitrogen sources often results in improved nitrogen use efficiency. The organic matter slows nitrogen volatilization and leaching, while the mineral nitrogen provides immediate availability to meet crop demand during critical growth stages. Wider planting distances likely reduced intra-specific competition, allowing plants greater access to light, water, and nutrients. This can enhance root development and nutrient uptake, which is reflected in higher nutrient concentrations in leaves. These findings align with Doklega & Imryed, (2020); Mengistu *et al.* (2021).

3.Growth criteria

Data presented in Tables 7 and 8 clearly illustrate that the growth parameters of lettuce *i.e.,* plant fresh and dry weight, plant height, number of uncurled leaves, and the fresh weight of uncurled leaves were significantly influenced by the interaction between organic manure (ChM) application rates, nitrogen fertilizer levels, and planting distances during both growing seasons (2016/17 and 2017/18). In general, the use of ChM at increasing rates led to a consistent improvement in all measured growth attributes. Among the nitrogen levels, the highest dose consistently resulted in enhanced growth performance, particularly when combined with the highest rate of ChM. This effect was further strengthened when plants were grown at wider planting distances, suggesting that adequate spacing may facilitate better nutrient uptake and reduce competition, thereby optimizing growth under favorable nutritional conditions. Moreover, the combined treatment of high ChM rate and high nitrogen level under wider spacing produced the most vigorous plants across all traits. On the other hand, the control treatments (without ChM and nitrogen) recorded the lowest values, reflecting the limited availability of nutrients and the suboptimal growing conditions.

Interestingly, moderate levels of nitrogen combined with medium ChM application also showed notable improvements in growth traits compared to untreated controls, indicating a potential for reduced input use while still achieving satisfactory growth. This suggests that organic amendments can partially substitute chemical fertilizers and improve soil fertility and structure, contributing to sustainable lettuce production.

Table 7. Effect of the triple interaction between ChM rates, nitrogen levels and planting distances on growth criteria of lettuce during the growing season of 2016/17

Parameters Treatments			Plant fresh weight, g	Fresh weight of uncurled leaves, g	Plant height, cm	No. of uncurled leaves	Plant dry weight, g
Control (without organic fertilizer)	Control (without N)	Planting distance of 20×60 cm	512.6p	120.33v	11r	11.33u	13.43o
		Planting distance of 40×60cm	512.66p	121.33v	10.38r	11.7t	13.43o
	90 kg N ha^{-1}	Planting distance of 20×60 cm	526.0mo	133.33s	14.2n	13.36q	13.78o
		Planting distance of 40×60cm	529.66in	137.33r	14.6m	13.5pq	13.87o
	180 kg N ha^{-1}	Planting distance of 20×60 cm	557.66hj	162.33m	16.76hi	14.73lm	14.61n
		Planting distance of 40×60cm	562.0gi	165.33l	17.06h	14.86l	14.72n
	270 kg N ha^{-1}	Planting distance of 20×60 cm	597.33c	192.33f	19.5bc	16.1g	15.65klm
		Planting distance of 40×60cm	588.33cd	193.00f	19.63b	16.8f	15.4lm
Addition of ChM at rate of 10 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	515.0op	121.33v	12.1q	11.7t	15.4m
		Planting distance of 40×60cm	516.33op	122.33v	12.3q	11.8t	15.44klm
	90 kg N ha^{-1}	Planting distance of 20×60 cm	531.33l	141.66q	14.8m	13.7op	15.89kl
		Planting distance of 40×60cm	535.33lm	147.66p	15.3l	13.76o	16.01k
	180 kg N ha^{-1}	Planting distance of 20×60 cm	567.66fh	169.66k	17.6g	15.13k	16.97j
		Planting distance of 40×60cm	572.0eg	173.66j	18.1f	15.4j	17.1j
	270 kg N ha^{-1}	Planting distance of 20×60 cm	594.33c	198.33e	19.7b	16.86f	17.77i
		Planting distance of 40×60cm	598.0c	202.66d	20.13a	17.23e	17.88i
Addition of ChM at rate of 20 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	520.66np	125.33u	12.43q	12.03s	21.92h
		Planting distance of 40×60cm	520.33np	125.66tu	12.86p	12.46r	21.90h
	90 kg N ha^{-1}	Planting distance of 20×60 cm	536.33 Km	148.66p	15.53kl	13.86o	22.58g
		Planting distance of 40×60cm	538.33kl	151.66o	15.8k	14.16n	22.66g
	180 kg N ha^{-1}	Planting distance of 20×60 cm	582.0de	176.00ij	18.56e	15.56ij	24.50f
		Planting distance of 40×60cm	577.33df	178.33hi	18.9de	15.36j	24.30f
	270 kg N ha^{-1}	Planting distance of 20×60 cm	616.0b	203.33d	2013a	17.73d	25.93e
		Planting distance of 40×60cm	662.0a	2011.33c	20.16a	18.6c	27.87d
Addition of ChM at rate of 30 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	522.33np	128.33t	13.2op	12.63r	27.78d
		Planting distance of 40×60cm	526.33mo	133.33s	13.53o	12.66r	28.00d
	90 kg N ha^{-1}	Planting distance of 20×60 cm	547.0jk	154.00o	16.23j	14.3n	29.1c
		Planting distance of 40×60cm	553.0ij	159.00n	16.53ij	14.63m	29.42c
	180 kg N ha^{-1}	Planting distance of 20×60 cm	579.66de	181.00gh	19.16cd	15.76hi	30.83b
		Planting distance of 40×60cm	580.66de	183.33g	19.23cd	15.83h	30.89b
	270 kg N ha^{-1}	Planting distance of 20×60 cm	667.0a	216.00b	20.13a	19.1b	35.48a
		Planting distance of 40×60cm	669.66a	220.33a	20.36a	19.86a	35.62a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

Table 8. Effect of the triple interaction between ChM rates, nitrogen levels and planting distances on growth criteria of lettuce during the growing season of 2017/18

Parameters Treatments			Plant fresh weight, g	Fresh weight of uncurled leaves, g	Plant height, cm	No. of uncurled leaves	Plant dry weight, g
Control (without organic fertilizer)	Control (without N)	Planting distance of 20×60 cm	415s	96jk	10.16u	10.5u	9.08w
		Planting distance of 40×60cm	518qr	118.33gj	11t	10.33u	11.34v
	90 kg N ha^{-1}	Planting distance of 20×60 cm	548pq	111.33hk	14.36n	12.53pq	12.00uv
		Planting distance of 40×60cm	517.66op	120.0gj	14.43n	12.78op	12.51tuv
	180 kg N ha^{-1}	Planting distance of 20×60 cm	578.33np	110.66hk	15.96ij	13.92k	12.66stu
		Planting distance of 40×60cm	634.33jl	137.66eg	16.76h	13.95k	13.89qrs
	270 kg N ha^{-1}	Planting distance of 20×60 cm	727.66g	139eg	17.83de	15.43g	15.93op
		Planting distance of 40×60cm	747ef	124.33fi	17.93de	16.3f	16.36no
Addition of ChM at rate of 10 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	495.66hi	88.66k	11.33st	10.93t	11.3v
		Planting distance of 40×60cm	5166.33qr	116.33gj	11.66s	11.43s	11.77uv
	90 kg N ha^{-1}	Planting distance of 20×60 cm	593.66mo	146.33df	14.9m	12.8op	13.53rst
		Planting distance of 40×60cm	591.33mo	108.33ik	14.36l	12.94no	13.48rst
	180 kg N ha^{-1}	Planting distance of 20×60 cm	638.66jk	117.66gj	16.28i	14.43j	14.56qr
		Planting distance of 40×60cm	654ij	114.66gj	16.83h	14.7hi	14.91pq
	270 kg N ha^{-1}	Planting distance of 20×60 cm	771.66df	138.66eg	18.13cd	16.76e	17.59mn
		Planting distance of 40×60cm	782.33ce	130.33fi	18.36bc	16.83e	17.84m
Addition of ChM at rate of 20 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	571.66op	165.33bd	12.53q	11.6rs	20.12l
		Planting distance of 40×60cm	598.66lo	135.66eh	12.1r	11.76r	21.07kl
	90 kg N ha^{-1}	Planting distance of 20×60 cm	602ko	136eh	15.43kl	13.06no	21.19kl
		Planting distance of 40×60cm	629.33jm	134eh	15.68jl	13.26mn	22.15jk
	180 kg N ha^{-1}	Planting distance of 20×60 cm	641.33j	137eg	17.23g	14.53ij	22.57j
		Planting distance of 40×60cm	712.33gh	181bc	17.30fg	14.76hi	25.07i
	270 kg N ha^{-1}	Planting distance of 20×60 cm	806cd	156.33ce	18.56ab	17.6d	28.37h
		Planting distance of 40×60cm	817.66c	128.33fi	18.72ab	18.33c	28.78h
Addition of ChM at rate of 30 ton ha^{-1}	Control (without N)	Planting distance of 20×60 cm	591.33mo	128.33fi	13.26p	11.86r	29.44gh
		Planting distance of 40×60cm	615.33jn	139.33eg	13.66o	12.3q	30.64fg
	90 kg N ha^{-1}	Planting distance of 20×60 cm	620.33jm	125fi	15.8jk	13.5lm	30.89f
		Planting distance of 40×60cm	654.33ij	127fi	15.81jk	13.66kl	30.58e
	180 kg N ha^{-1}	Planting distance of 20×60 cm	685.66hi	134eh	17.62ef	14.86h	34.14d
		Planting distance of 40×60cm	740fg	185ab	17.81de	14.88h	36.85c
	270 kg N ha^{-1}	Planting distance of 20×60 cm	869.33b	168.66bd	18.73ab	18.66b	43.29b
		Planting distance of 40×60cm	921.3a	208.33a	18.82a	19.06a	45.88a

Means within a row followed by a different letter (s) are statistically different at a 0.05 level

CONCLUSION

The present study demonstrates the significant potential of integrating organic and mineral nitrogen fertilization under different planting distances to optimize the growth and yield of lettuce. The combined application of chicken manure at 30 tons ha^{-1} and 180 kg N ha^{-1}, particularly under wider spacing (20×60 cm), led to notable improvements in head weight, and total yield. Interestingly, this integrated treatment yielded results comparable to or better than the sole application of high mineral nitrogen (270 kg N ha^{-1}) without ChM, emphasizing the efficiency of organic manure as a partial substitute for mineral nitrogen fertilizers. These findings underscore the role of organic amendments in enhancing nitrogen use efficiency, improving soil properties, and supporting sustainable crop production. Furthermore, the study suggests that adjusting planting distances alongside balanced fertilization can optimize lettuce productivity while minimizing the environmental and economic costs associated with excessive chemical fertilizer use. Generally, the integration of organic and mineral fertilization, combined with proper planting density, offers a promising strategy for sustainable and efficient lettuce cultivation, particularly under conditions aiming to reduce the dependency on synthetic nitrogen inputs.

REFERENCES

Doklega, S., & Imryed, Y. F. E. (2020). Effect of vermicompost and nitrogen levels fertilization on yield and quality of head lettuce. Journal of Plant Production, 11(12), 1495-1499.

Mengistu, F. G., Tabor, G., Dagne, Z., Atinafu, G., & Tewolde, F. T. (2021). Effect of planting density on yield and yield components of lettuce (Lactuca sativa L.) at two agro-ecologies of Ethiopia. African Journal of Agricultural Research, 17(4), 549-556.

Raina, R., & Mazahar, S. (2022). Nitrogen: A key macronutrient for the plant world. In Advances in Plant Nitrogen Metabolism (pp. 19-27). CRC Press.

Ryan, J., Estefan, G., & Rashid, A. (2001). Soil and plant analysis laboratory manual. ICARDA.

Shatilov, M. V., Razin, A. F., & Ivanova, M. I. (2019). Analysis of the world lettuce market. In IOP Conference Series: Earth and Environmental Science (Vol. 395, No. 1, p. 012053). IOP Publishing.

Snedecor, G. W., & Cochran, W. (1967). Statistical methods. Iowa state. University Press, 327, 12.

Tandon, H. L. S. (2005). Methods of analysis of soils, plants, waters, fertilizers & organic manures. Fertilizer Development and Consultation Organization.

Witte, C. P. (2011). Urea metabolism in plants. Plant Science, 180(3), 431-438.

تحسين إنتاجية الخس باستخدام زرق الدجاج تحت مسافات زراعة مختلفة ومستويات متفاوتة من النيتروجين

حسن بن إدريس البابا [١] ،يوسف فرج الشريف إمريض[٢]، أحمد محمد أبوزيتونة[٣]، أسامة سعد بلقاسم[٤]

[١]قسم الإنتاج النباتي- كلية الزراعة- جامعة الكفرة- ليبيا
[٢]قسم الإنتاج النباتي- كلية الزراعة- جامعة بني غازي- ليبيا
[٣]قسم النبات- كلية العلوم- جامعة الكفرة-ليبيا
[٤]قسم البستنه- كلية الزراعة- جامعة عمر المختار/ البيضاء - ليبيا

الملخص

لدراسة إمكانية استخدام الأسمدة العضوية كبدائل جزئية للأسمدة النيتروجينية المعدنية بهدف تحسين إنتاجية الخس وتقليل الاستخدام المفرط للنيتروجين المعدني وتعزيز الممارسات الزراعية المستدامة، تم تنفيذ تجربة حقلية خلال موسمي الشتاء المتتاليين ٢٠١٦/٢٠١٧ و٢٠١٧/٢٠١٨، باستخدام نبات الخس كنبات تجريبي. وُضعت التجربة وفق تصميم القطاعات المنشقة مرتين، حيث خُصصت القطاعات الرئيسية لأربعة مستويات من السماد العضوي (زرق الدواجن بمعدلات ٠، ١٠، ٢٠، و٣٠ طن/هكتار)، في حين شملت القطاعات المنشقة الاولي أربعة مستويات من السماد النيتروجيني (يوريا ٤٦٪ نيتروجين بمعدلات ٠، ٩٠، ١٨٠، و٢٧٠ كجم نيتروجين/هكتار). أما القطاعات المنشقة الثانية فقد خُصصت لمسافتين من الزراعة (٢٠ × ٦٠ سم و٤٠ × ٦٠ سم). شملت القياسات المحصول الطازج الكلي، و المحصول الجاف الكلي، والمحصول الكلي للرؤوس، والوزن الطازج للرأس، وقطر الرأس والمحتوي من النيتروجين والفسفور والبوتاسيوم. أظهرت النتائج أن المعاملة الأفضل خلال الموسمين كانت الجمع بين ٣٠ طن/هكتار من سماد زرق الدواجن و٢٧٠ كجم نيتروجين/هكتار مع المسافة الأقرب بين النباتات، حيث حققت أعلى قيم لكل من المحصول الكلي والمحصول التسويقي. ومن الجدير بالذكر أن معاملة ٣٠ طن/هكتار من سماد زرق الدواجن مع ١٨٠ كجم نيتروجين/هكتار تحت نفس مسافة الزراعة (٢٠×٦٠ سم) أعطت نتائج لم تختلف معنوياً عن تلك الناتجة عن استخدام ٢٧٠ كجم نيتروجين/هكتار بدون إضافة عضوية. وتبرز هذه النتيجة الدور الهام للأسمدة العضوية في الإسهام الجزئي في تزويد النبات بالنيتروجين.