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EFFICIENCY OF LEVELS OF PREPARED SLOW-RELEASE FERTILIZERS (NPK-CHITOSAN), ORGANIC MANUREAND INCUBATION PERIODS ON NITROGEN AVAILABILITY IN TWO DIFFERENT TEXTURE SOILS*

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ABSTRACT

The study was conducted at laboratory experiment included a completely randomized design (CRD) to study the efficiency of NPK-Chitosan fertilizers derived from shrimp shells with a ratio of1:1,1:2and 1:3 (NPK-Chitosan) (coating and mixing) at four fertilizers levels (0,500,1000 and 2000 mg kg^{-1} soil) and two levels of organic fertilizer (0 and 2.5%) Cow waste in terms of nitrogen availability in two types of soil (Silty clay and sandy loam soil comparing with NPK15-15-15 fertilizer (commercial) control treatment and incubated for four periods (7, 14, 28, and 56 days) to evaluate nitrogen availability. The results showed that adding fertilizers and organic fertilizer significantly increased the availability of nitrogen in both soils, NPK-Chitosan fertilizers, with a ratio of 1:3 coating and 1:3 mixing treatments, outperformed control treatment (fertilizer NPK alone) in increasing of available nitrogen. The results also revealed a significant effect of fertilizer levels on increasing of nitrogen concentration in both soils. The concentration increased with higher fertilizer level, (2000 mg kg^{-1} soil) achieving the highest nitrogen values of both soils, 90.9 and 91.47 mg kg^{-1} soil, respectively, with a significant difference compared to 500 and 1000 mg kg^{-1} soil levels. Furthermore, the 1000 mg kg^{-1} soil level outperformed the NPK fertilizer (control treatment). The results revealed a significant interaction effect between type and level of fertilizer on nitrogen available concentration. The treatment NPK-Chitosan fertilizer with a ratio of 1:3 for coating at level of 2000 mg kg^{-1} soil outperformed the other treatments, providing the highest nitrogen concentration of 129.00 and 167.40 mg kg^{-1} soil for both soils, respectively. The availability of the element increased with higher levels of added fertilizers and the addition of organic matter, but decreased with longer incubation periods.

Keywords: NPK-Chitosan Fertilizer, available nitrogen, organic manure, calcareous soils.

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INTRODCTION

Chitosan is a natural polymer a chain unit ranging from 2000 to 3000. It is the most abundant polymer of multiple sugar units in nature and has a molecular weight ranging from 100,000 to 1,200,000 Daltons, depending on the preparation method change PR., [7]. Chitosan is the second most widely spread organic compound after cellulose in nature, with a molecular formula of $(C_6H_{11}O_4N)$ n Dash, M. [9]. It is extracted from various natural sources and constitutes about 20-30% of the waste and shells of crustaceans such as shrimp, crab, lobster, and crayfish. Chitosan is obtained by removing the acetyl groups from chitin, which contains (60-100) % N-acetyl-glucosamine in the polymer chain Pandey Priyal., [17]. After removing the acetyl group, Chitosan becomes positively charged and can adsorb any negatively charged substance. Chitosan has been used in various agricultural applications as an antiviral and antifungal agent and seed coating material to enhance germination speed, root elongation, and plant resistance to water and salt stress. Puspita. A., G. [20] mentioned that mineral fertilizers, such as urea fertilizer, face problems in soil, which often has low efficiency in calcareous and sandy soils due to volatilization and leaching process. The merits of producing crops using organic versus inorganic methods. No system is ideal and each system has its own advantages and limitations [10].

A polymeric fertilizer was made from bentonite clay with Chitosan to enhance urea fertilizer efficiency. Parvin *et al.* [18] studied the effect of different levels of Chitosan (0, 80, and 120) ppm added to the soil and (0, 60, 80, and 100 ppm) foliar spray on tomato plants and their interaction on the yield and quality of tomato fruits, the results showed a significant difference in the number of leaves, clusters, tomato yield, and vitamin C content for the treatment with added Chitosan. The treatment also had higher amounts of calcium, potassium, and phosphorus in the fruits with soil addition and foliar spray. Milani, P. [14] emphasized the importance of polymeric materials in the production of slow-release fertilizers, and among these natural polymeric materials is Chitosan, which can be used with mineral fertilizers for nitrogen availability. Abouchenaria [2] highlighted the importance of mixing and blending Chitosan with mineral fertilizers and amendments to increase soil water retention and enhance the efficiency of mineral fertilizers. Abdel-Aziz [1] found that nitrogen, phosphorus, and potassium-loaded chitosan nanoparticles provided high productivity for wheat crops grown in sandy soil in Egypt when the fertilizer was applied as a foliar spray, the yield increased by 23.5% compared to the traditional mineral fertilizer (NPK) treatment. Mansour and El-Mesairy [12] conducted a study by adding different levels of Chitosan (0, 150, 100, and 200 ppm) and humic acid (0, 2, 4 and 6 kg ha^{-1}) as a foliar spray on okra plants, the highest yield and best quality were obtained using 200 ppm Chitosan and 6 kg ha^{-1} of humic acid. Puspita [20] found that preparing a polymer fertilizer from Chitosan with potassium as a slow-release fertilizer was better than other mineral potassium fertilizers. The purpose of testing the efficiency of organic–mineral fertilizers at different rates, levels, and incubation periods for nitrogen availability in two soils with different textures.

MATERIALS AND METHODS

A laboratory experiment was conducted at the College of Agriculture, University of Basra, during the year 2021-2022. The study included the preparation of NPK-Chitosan fertilizers prepared from shrimp shells, NPK-Chitosan fertilizer was prepared in two formulations: mixed NPK-Chitosan and coated NPK-Chitosan with three ratios (1:1 to 1:3) at four levels (0, 500, 1000 and 2000 mg kg^{-1} soil) equal to 465 N mg kg^{-1} soil, and two Organic Manure levels (0 and 2.5%), with in terms of the availability of nitrogen in different texture (clay loam and sandy loam) from Basra province and using CRD Completely Randomized Design to two types of soils. NPK fertilizer (15-15-15) was used as a control treatment, the treatments were as below:

1-NPK -Chitosan (1:1) mixed fertilizer.
2-NPK -Chitosan (1:1) coated fertilizer.
3-NPK -Chitosan (2:1) mixed fertilizer.
4-NPK -Chitosan (2:1) coated fertilizer.
5-NPK -Chitosan (3:1) mixed fertilizer.
6-NPK -Chitosan (3:1) coated fertilizer.
7-NPK (control) (15-15-15).

Table 1 shows the chemical and physical properties of soils that were analyzed according to the methods described by Richards, L. [20], Black, C. [6], and Page, A. [16] available nitrogen according to Cresser & Parsons [8].

Three hundred grams (300 gm.) of dry soil (Silty Clay and Sandy Loam) was taken and sieved through a 2 mm sieve size. It was placed in plastic containers with a capacity of 500 grams. According to the treatments, (0 and 2.5%) (Fermented cattle manure residues) were added to the soils and incubated at 25°C for two weeks and moistened with distilled water up to 30% and 20% of filed capacity) respectively. After the soils were dried, the fertilizer treatments were added by mixing with the soils, and the soils were moistened up to field capacity according to the soil.

Type, then the soils were incubated at 25°C for the following periods (7, 14, 28, and 56 days). After incubation, the soils were ground to determine available nitrogen. The total number of treatments was (2×7×2×3×3) (soil×fertilizer formulations×Organic Manure fertilizer levels×Fertilizer levels×replicates) =252 experimental units for each period. 252 ×4 =1008 total experimental units for all periods.

RESULTS AND DISCUSSION

Effect of fertilizer types on nitrogen availability during incubation periods (figures 1 and 2) show the effect of the fertilizer type on available nitrogen concentration in silty clay soil and sandy loam soil for all incubation periods (7, 14, 28, and 56 days) comparing with control treatment (NPK). NPK-chitosan fertilize coated at 1:3 ratio showed the highest available nitrogen concentration in silty clay soil at 28- and 56-day incubation to reach 122.40 and 90.93 mg kg^{-1}soil respectively and the same treatment in sandy loam soil reached 93.33 and 76.08 mg kg^{-1} soil, respectively. In contrast, the control treatment showed decreased levels compared to NPK-chitosan treatment at a ratio 1:3 at the same periods to record a concentration of available nitrogen in silty clay soil treatment 128.53% and 88.53% respectively, and for Sandy Loam soil 108.04% and 102.55%

respectively, while NPK fertilizer alone (Control) gave the highest concentration of available nitrogen at first period (14 days) for both soils (figures 1 and 2). While available nitrogen for the NPK fertilizer (control) decreased after 28 and 56 days in the silty clay soil to 53.56 and 48.23 mg kg^{-1} for 28 days and in the sandy loam soil to 44.86 and 37.56 mg kg^{-1} for 56 days, respectively. It demonstrates the role of chitosan in preventing nitrogen loss from the soil.

The early stages of incubation and gradually releasing nitrogen continuously throughout the later stages of incubation. The increases significantly in the amount of available nitrogen in both soils treated with prepared fertilizers (NPK-chitosan) can be attributed to chitosan improves the use of nutrients, especially ammonium ions, and enhances its availability in the soil while reducing its loss through volatilization, especially in the sandy loam soil when mixed with chitosan.

Table 1: Chemical and physical properties of soils

Properties		Value	Value	Units
pH (1:1)		7.78	8.27	-
Electrical Conductivity (EC) (1:1)		3.55	4.36	dSm^{-1}
Cation Exchange Capacity (CEC)		11.34	24.14	Cmol. kg^{-1}
Organic Matter		5.69	7.73	g.kg^{-1}
Carbonate Minerals		259	315	g.kg^{-1} soil
Available Nitrogen		9.58	10.84	mg.kg^{-1}
Available Phosphorus		10.36	9.27	
Available Potassium		33.29	26.95	
Soluble Cations	Ca+2	10.47	13.83	mmol. L^{-1}
	Mg+2	7.61	9.72	
	Na+	11.98	27.51	
	K+	8.63	12.84	
Soluble Anions	Cl-	15.76	33.76	mmol. L^{-1}
	SO4-2	10.46	16.44	
	HCO3-	8.25	11.59	
	CO3-2	0.00	0.00	
Soil Fractions	Clay	128.50	445.70	g.kg^{-1}
	Silt	305.80	485.50	
	Sand	565.80	68.80	
Soil Texture	Sandy Loam		Silty Clay	Units

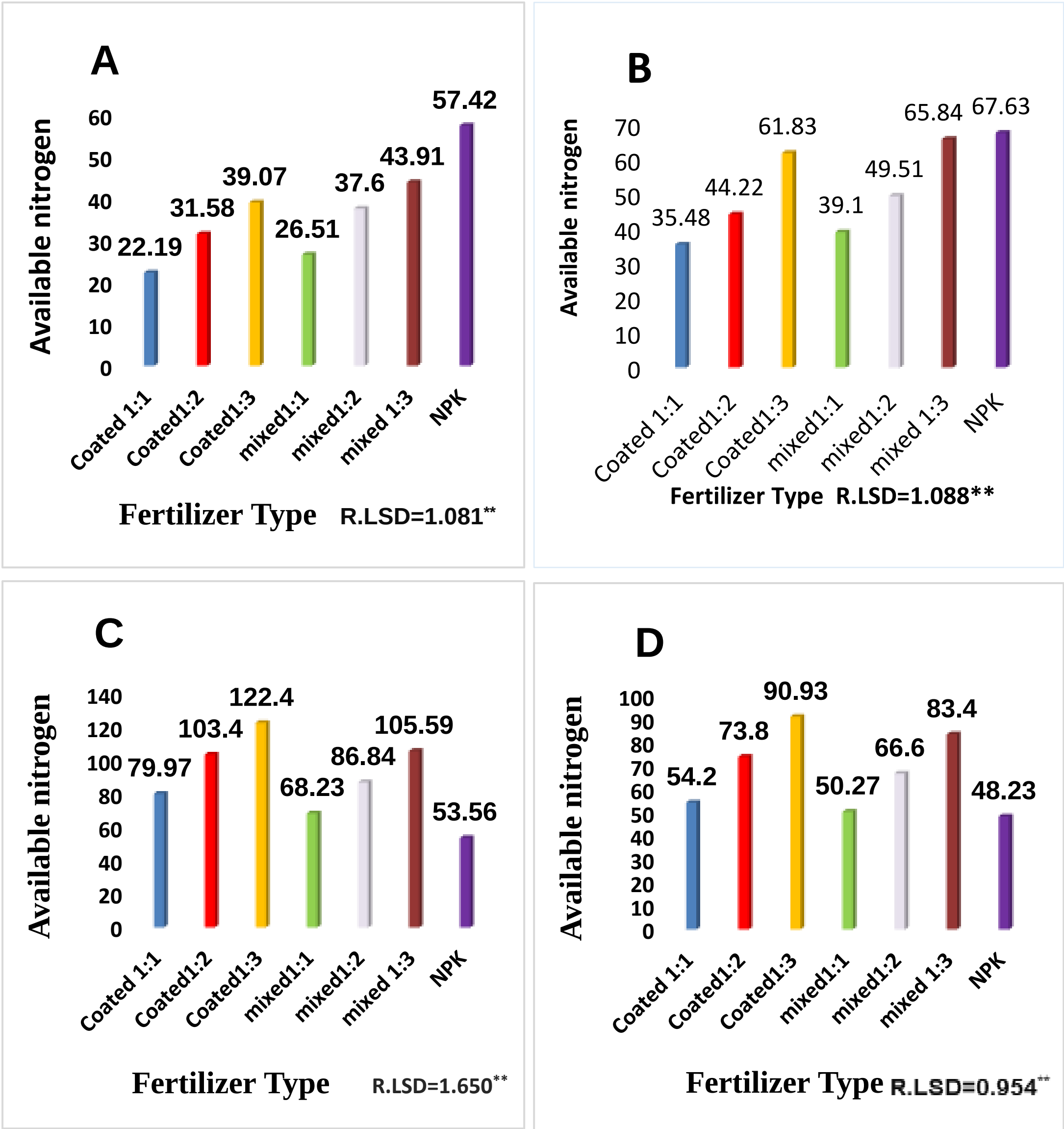

Fig.1: Effect of fertilizer type on available nitrogen concentration (mg N kg^{-1} soil) in silty clay soil during incubation periods (A: 7, B: 14, C: 28, D: 56) days.

Chitosan significantly contributes to the retention of ammonium ions in the soil, protecting them from volatilization and improving efficiency. It is consistent with the characteristics of slow-release fertilizers [4, 8]. These results were consistent with the findings of Noppakundilograt [15] and Nitrogen fertilizer applications at 60 and 80 kg ha^{-1} improved essential oil output and percentage of essential oil, suggesting that commercial native spearmint plants should get 60 kg Nha^{-1}. In conclusion, the amount of nitrogen applied may have an influence on spearmints vegetative.

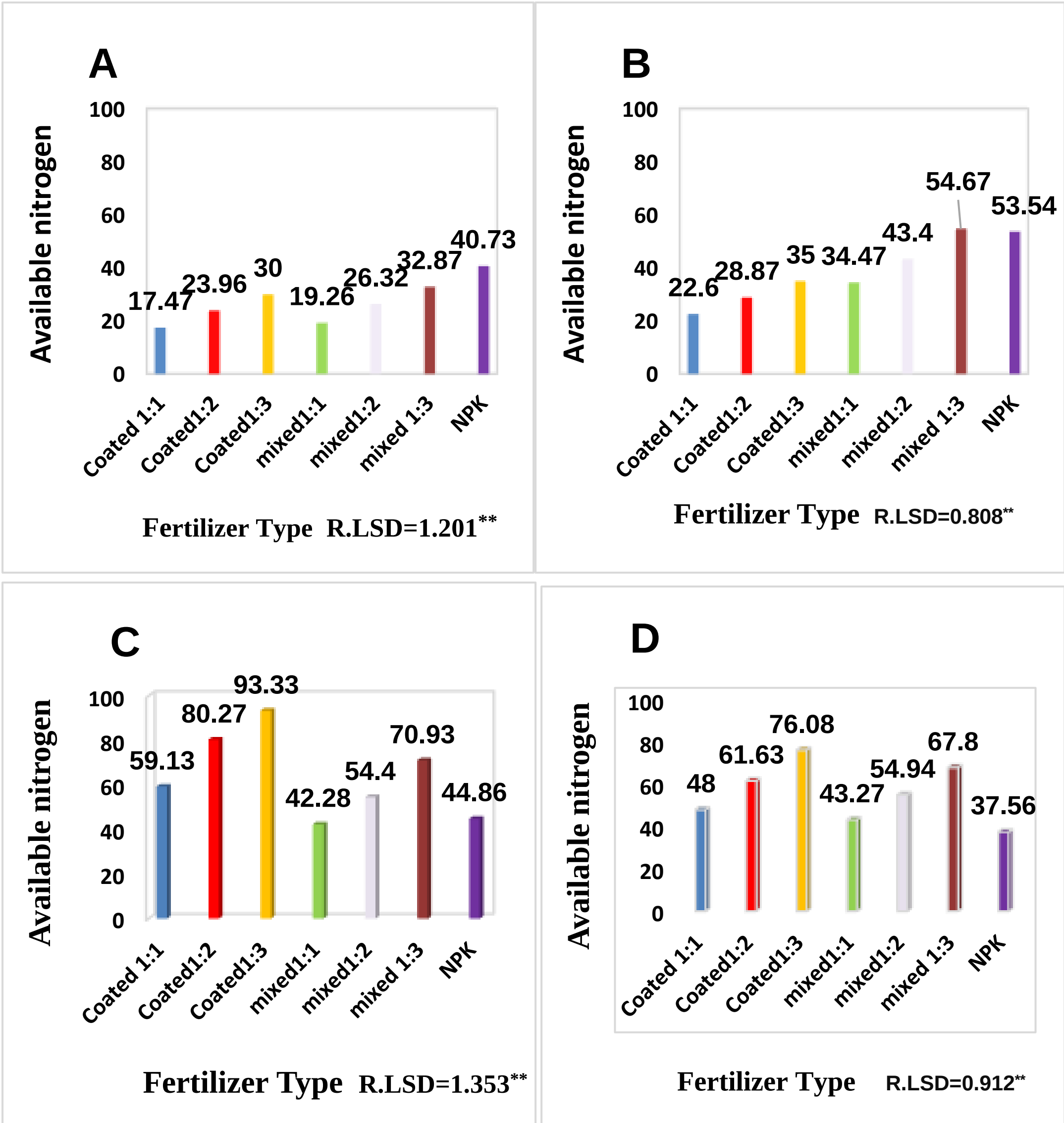

Fig.2: Effect of fertilizer type on available nitrogen concentration (mg N kg^{-1} soil) in Sandy Loam soil during incubation periods (A: 7, B: 14, C: 28, D: 56) days.

Growth and development: Ali and Haifaa [3] reported a significant increase in the concentration of available nitrogen in the soil by 84% nitrogen when adding NPK fertilizer granules treated with chitosan after 30 days compared to the control treatment.

The results shown in Figures 3 and 4 indicate that the amount of available nitrogen concentration in both soils increased with increasing fertilizer levels (500, 1000, and 2000 $mg.kg^{-1}$) for all incubation periods. This increase can be attributed to the higher amount of nitrogen added and its alignment with the addition of chitosan due to its nitrogen content (table 1). These findings were consistent with the results obtained by Parvin [18], who found an increase in soil nitrogen concentration.

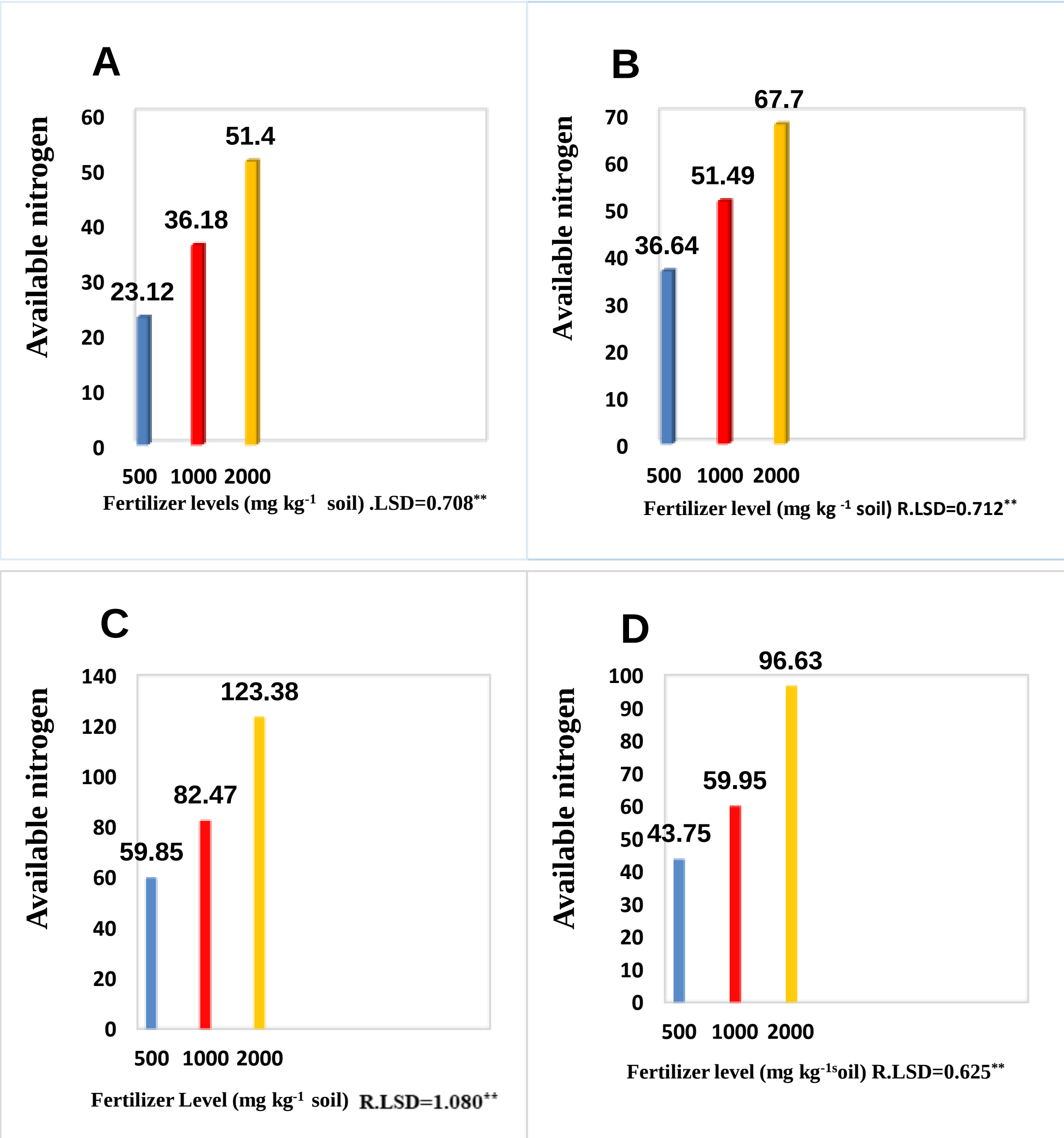

Fig.3: Effect of NPK-chitosan fertilizer level (mg kg^{-1} soil) on available nitrogen concentration (mg N kg^{-1} soil) in silty clay soil during incubation periods (A: 7, B: 14, C: 28, D: 56) days.

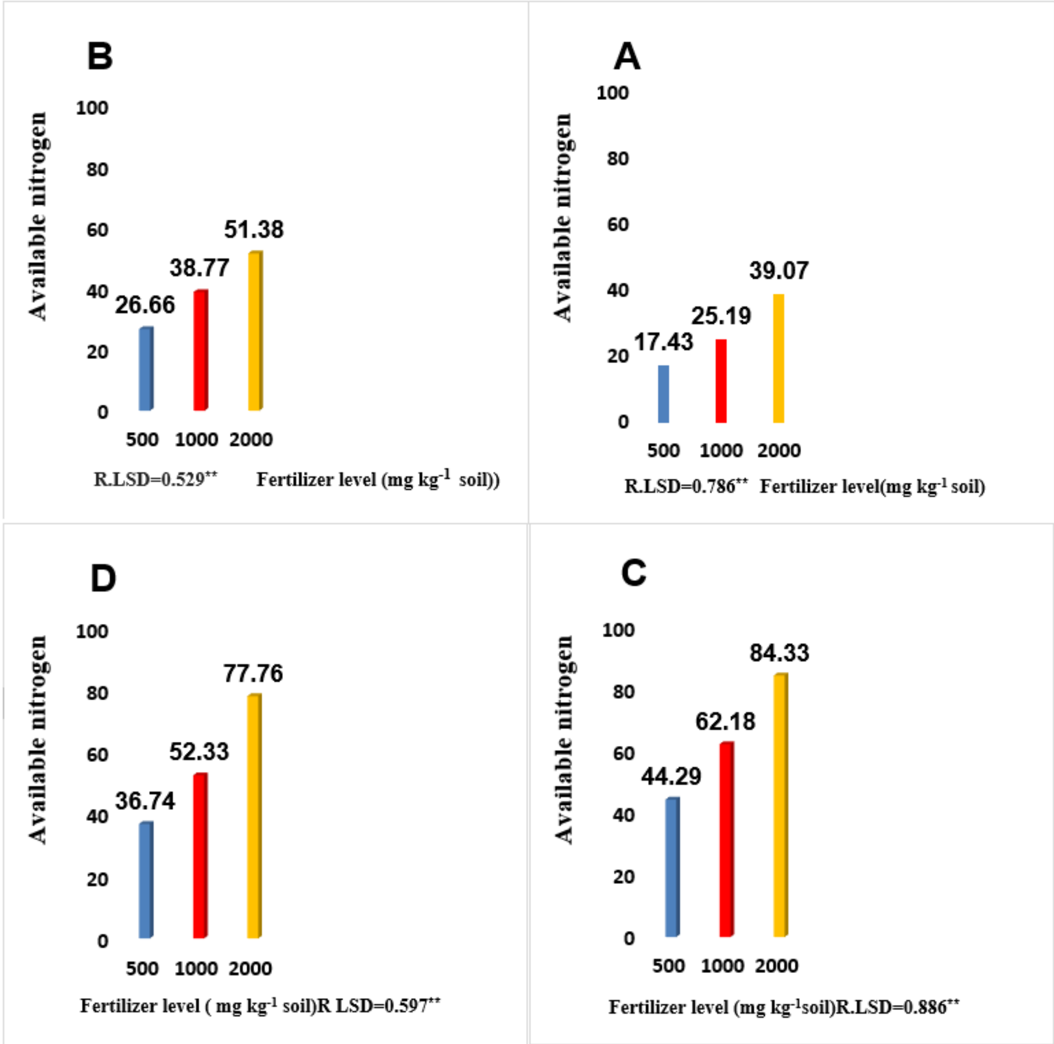

Fig.4: Effect of NPK-chitosan fertilizer level (mg kg^{-1} soil) on available nitrogen concentration (mg N kg^{-1} soil) in Sandy Loam soil during incubation periods (A: 7, B: 14, C: 28, D: 56) days.

The results in table 2 indicated that the amount of available nitrogen in both soils increased with the increasing levels of organic manure addition (0 and 2.5 %). The level of 2.5 % showed the highest concentration of available nitrogen in the soils for the incubation periods of 7, 14, 28, and 56 days for the silty clay soil (39.04, 55.00, 100.67 and 73.7 mg kg^{-1} soil, respectively) (figure 5). Similarly, in the Sandy Loam soil, the concentrations were 28.66, 42.6, 70.21, and 61.8 mg kg^{-1} soil (figure 6). These increases corresponded to percentage increases of 2.34%, 2.49%, 31.65%, and 23.14% for the silty clay soil and 11.08%, 20.78%, 58.52%, and 25.05% for Sandy Loam soil, respectively, compared to control treatment. Improves soil's chemical properties, particularly cation exchange capacity (CEC). It is attributed to the role of Organic Manure in ion.

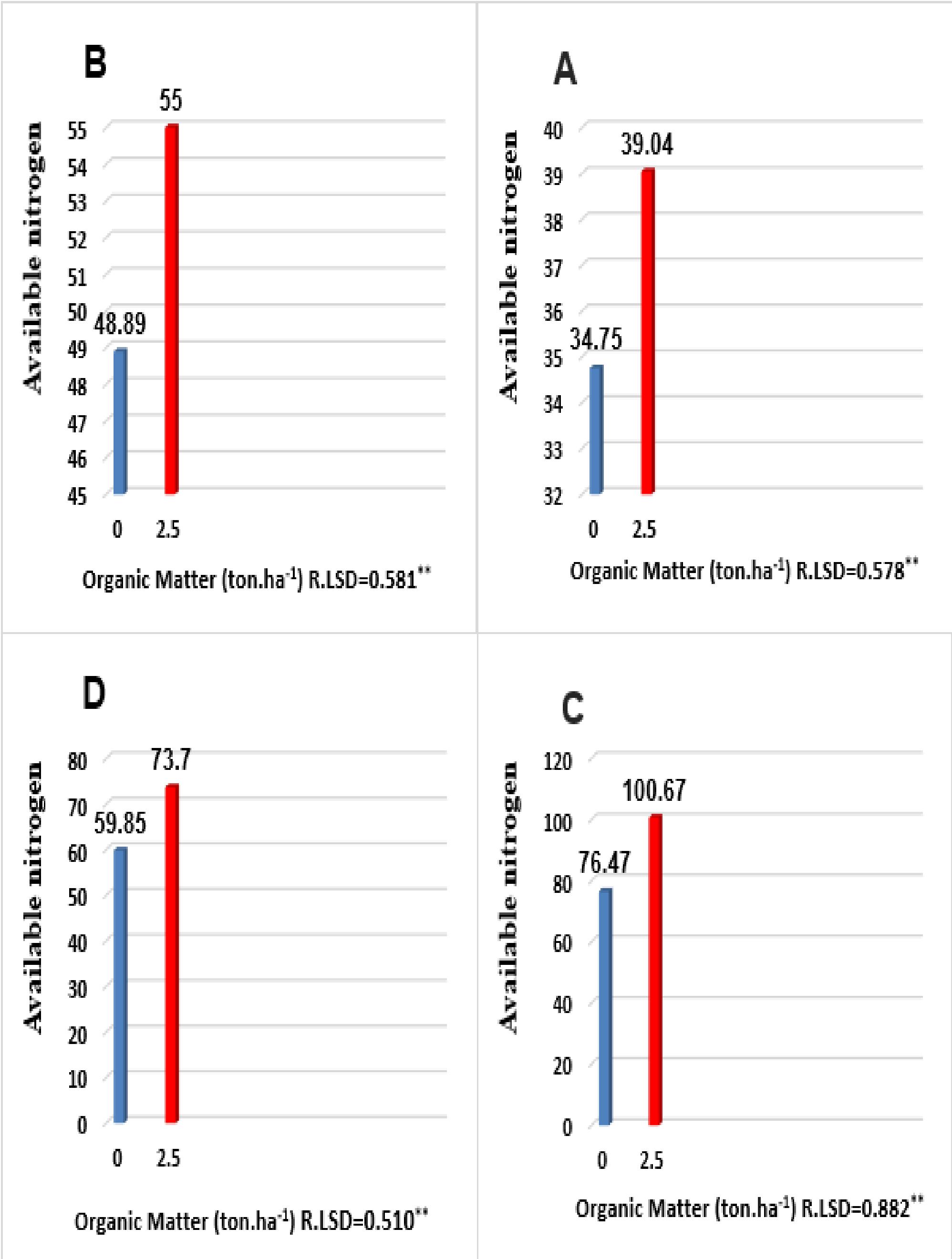

Fig.5: Effect of organic matter levels on available nitrogen concentration (mg N kg^{-1} soil) for silty clay soil for incubation periods (A: 7, B: 14, C: 28, and D: 56) days.

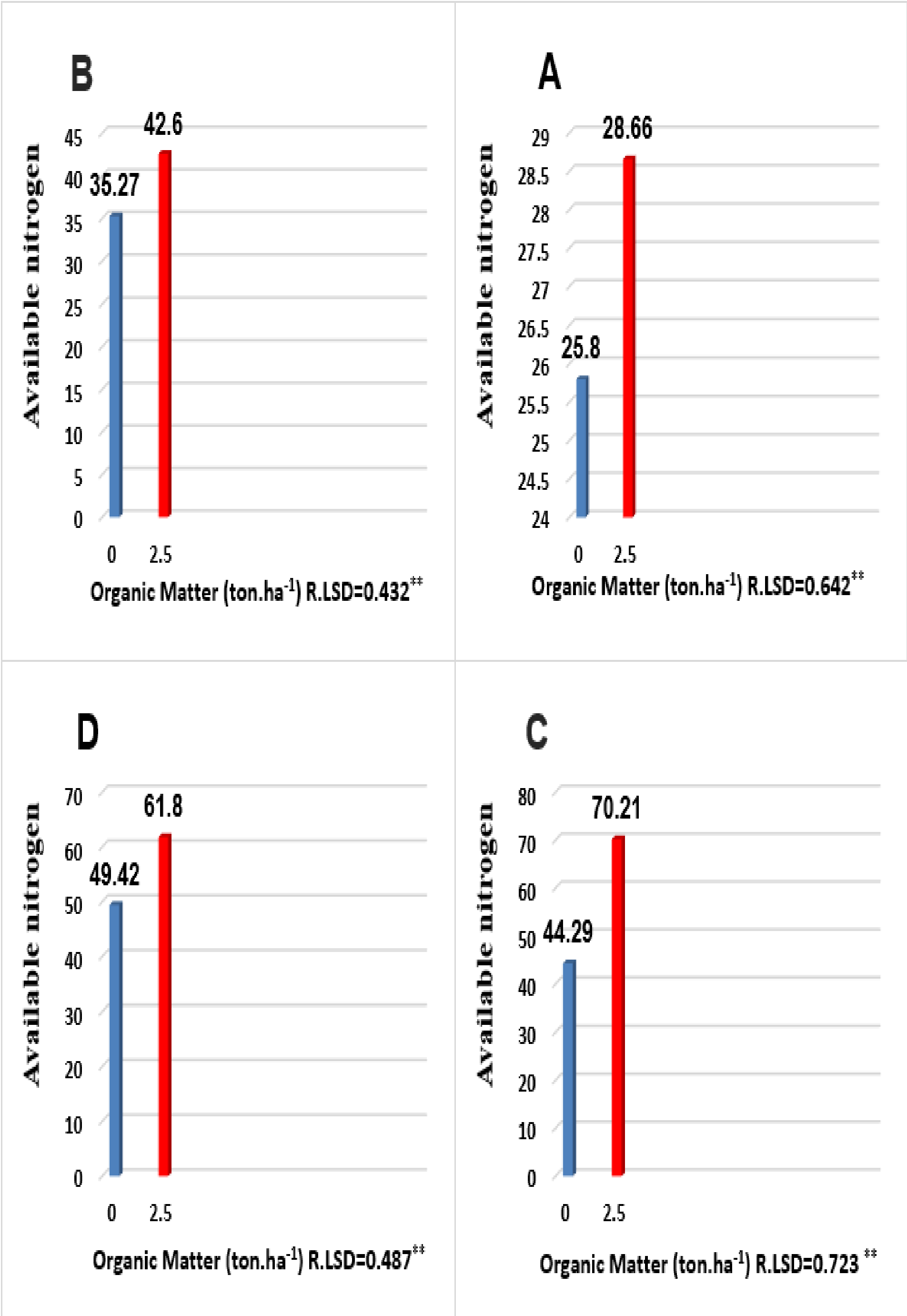

Fig.6: Effect of organic matter levels on available nitrogen concentration (mg N kg^{-1} soil) for sandy loam soil for incubation periods (A: 7, B: 14, C: 28, and D: 56) days.

Table 2: Effect of interaction between fertilizer type and levels of Organic Manure on available nitrogen concentration (mg N kg^{-1} soil) for the both soils at different incubation periods.

Incubation period (Days)	Fertilizer Type	Silty Clay Soil		Sandy Loam Soil	
		Organic Manure (%)		Organic Manure (%)	
		0	2.5	0	2.5
7	Coated 1:1	20.67	23.71	17.17	17.78
	Coated 1:2	30.00	33.16	21.51	26.40
	Coated 1:3	36.54	41.60	27.73	32.27
	Mixing 1:1	25.54	27.48	18.56	19.27
	Mixing 1:2	35.91	39.29	25.32	27.32
	Mixing 1:3	41.68	46.13	31.46	34.29
	NPK	52.91	61.93	38.88	42.59
	RLSD	1.529**		1.698**	
14	Coated 1:1	32.40	38.56	20.93	24.27
	Coated 1:2	41.87	48.56	26.13	31.60
	Coated 1:3	60.00	63.66	31.60	38.40
	Mixing 1:1	34.00	44.20	30.27	38.67
	Mixing 1:2	46.53	52.49	40.27	46.53
	Mixing 1:3	64.53	67.14	48.67	60.67
	NPK	62.88	72.38	49.00	58.09
	RLSD	1.538**		1.143**	
28	Coated 1:1	64.47	95.47	50.80	67.47
	Coated 1:2	83.73	123.07	71.20	89.33
	Coated 1:3	103.47	141.33	85.07	101.60
	Mixing 1:1	59.66	76.80	37.10	47.47
	Mixing 1:2	77.56	96.13	48.53	60.27
	Mixing 1:3	98.79	112.40	66.80	75.07
	NPK	47.65	59.47	39.44	50.27
	RLSD	2.333**		1.913**	
56	Coated 1:1	49.87	58.53	44.13	51.87
	Coated 1:2	65.20	82.40	56.19	67.07
	Coated 1:3	82.93	98.93	69.76	82.40
	Mixing 1:1	43.47	57.07	36.40	50.13
	Mixing 1:2	58.27	74.93	46.56	63.33
	Mixing 1:3	76.27	90.53	60.53	75.07
	NPK	42.96	53.51	32.36	42.77
	RLSD	1.350**		2.233**	

RLSD**= Indicate that there are significant differences between the coefficients at a significant level ($P \leq 0.001$) for the type of fertilizer and the levels of Organic Manure in the nitrogen readiness of the two study soils.

With increasing rates of chitosan application (0, 80, and 120 ppm), and with results of Puspita, A. *et al* [19].

Exchange and retention, as well as reducing nitrogen loss and releasing it in the soil, thereby increasing its availability. The interaction between type of fertilizer and level of Organic Manure addition there was a significant increase in available nitrogen. Concentration in Silty Clay and Sandy Loam soils for all incubation periods (7, 14, 28, and 56 days) (table 2). The treatment NPK-chitosan fertilizer coated with chitosan at 1:3 ratio, and 2.5 % Organic Manure achieved the highest values with significant differences compared to the other treatments at 28- and 56-day incubation Periods for both soil types. The respective values were 141.33 and

98.93 mg.kg^{-1} soil for silty clay soil and 101.60 and 82.40 mg.kg^{-1} soil for sandy loam soil, respectively, followed by the treatment of NPK-chitosan fertilizer mixed with chitosan at a ratio of 2.5 % Organic Manure which gave values of (89.33 and 75.07 mg kg^{-1} for silty clay on 56 days) and (112.33 and 90.53 mg.kg^{-1} for silty clay on 28 days) after an incubation period of 28 and 56 days, respectively.

Table 3: Effect of interaction between fertilizer types and level of fertilizer (mg.kg^{-1} soil) on available nitrogen concentration (mg N.kg^{-1} soil) for all incubation periods in the studied soils

Period Incubation Days	Fertilizer Type	Silty Clay Soil			Sandy Loam Soil		
		Fertilizer Level (mg.kg^{-1} soil) NPK-Chitosan			Fertilizer Level (mg.kg^{-1} soil) NPK-Chitosan		
		500	1000	2000	500	1000	2000
7	Coated 1:1	12.60	20.90	33.07	9.50	17.30	25.62
	Coated 1:2	20.93	30.60	43.20	14.47	22.20	35.20
	Coated 1:3	24.37	39.60	53.25	19.40	29.00	41.60
	Mixing 1:1	14.40	26.00	39.13	11.60	17.45	28.73
	Mixing 1:2	25.67	34.80	52.33	16.48	24.15	38.33
	Mixing 1:3	28.63	43.90	59.18	20.60	32.30	45.72
	NPK	35.21	57.45	79.60	29.97	33.93	58.30
	RLSD	1.873**			2.080**		
14	Coated 1:1	21.60	38.30	46.53	15.40	21.60	30.80
	Coated 1:2	30.60	43.20	58.87	18.20	27.40	41.00
	Coated 1:3	51.73	59.43	74.32	24.00	34.80	46.20
	Mixing 1:1	24.00	41.90	51.40	20.00	36.20	47.20
	Mixing 1:2	34.20	46.53	67.80	30.20	43.80	56.20
	Mixing 1:3	52.80	63.32	81.40	42.40	52.60	69.25
	NPK	41.58	67.74	93.58	36.40	54.98	69.25
	RLSD	1.884**			1.399**		
28	Coated 1:1	49.60	73.40	116.90	39.60	56.00	81.80
	Coated 1:2	70.00	98.00	142.20	53.20	77.80	109.80
	Coated 1:3	86.00	113.80	167.40	62.00	89.00	129.00
	Mixing 1:1	40.97	63.40	100.32	28.25	46.40	52.20
	Mixing 1:2	59.80	83.20	117.53	38.60	51.20	73.40
	Mixing 1:3	76.00	93.68	147.10	58.00	68.60	86.20
	NPK	36.61	51.83	72.24	30.40	46.23	57.93
	RLSD	2.858**			2.343**		
56	Coated 1:1	38.20	46.60	77.80	32.20	40.60	71.20
	Coated 1:2	49.60	61.00	110.80	39.20	51.48	94.20
	Coated 1:3	55.20	86.60	131.00	47.60	68.43	112.20
	Mixing 1:1	32.60	44.60	73.60	27.00	42.60	60.20
	Mixing 1:2	45.60	58.20	96.00	38.20	51.40	75.23
	Mixing 1:3	52.80	75.40	122.00	48.60	70.40	84.40
	NPK	32.28	47.22	65.20	24.37	41.40	46.92
	RLSD	1.653**			1.579**		

RLSD= Indicate that there are significant differences between the coefficients at a significant level ($P \leq 0.001$) for the type of fertilizer and the levels of Organic Manure in the nitrogen readiness of the two study soils.**

The effect of type of fertilizer and level of Organic Manure reduced nitrogen loss from soils and increases its availability. On the other hand, NPK fertilizer at the level of 0 % soil (control) gave the lowest rates of available nitrogen values in the studied soils after incubation periods of 28 and 56 days, which Results in figures 5 and 6 indicate the effect of Organic manure addition on available nitrogen concentration, it was increased with increasing of Organic manure level (2.5%) for both soils and it was reached to highest value at 28 day of incubation (100.67 mg N kg^{-1} soil for silty clay soil and 70.21 mg kg^{-1} soil for sandy loam soil). It indicates the role of Organic Manure in reducing ammonia volatilization or immobilization by soil microorganisms (Assimilation), which was consistent with the findings of Behboudi [5] regarding the use of chitosan with chemical fertilizers to increase the soil's ability to retain nutrients during plant growth stages and enhance its availability, and organic manure enhances plant growth and resistance the environmental stress and increases seed [17, 22] with chitosan at a ratio of 1:3 and NPK fertilizer mixed with chitosan at a ratio of 1:3 at a level of 2000 mg kg^{-1} soil over the other levels is attributed to the content of available nitrogen from chitosan (Table 1) and considering chitosan as a slow-release fertilizer, especially when used with chemical fertilizers, which results in the preparation of the soil with available nitrogen during incubation. It is consistent with the findings of Malerba and Cerana [11].

The dual interaction between fertilizer concentration and the level of organic manure addition is significant. They affected available nitrogen content during most of the incubation periods, except for the 7-28 day incubation periods in clayey soil (Table 4), which were insignificant. The treatment with a fertilizer level of 2000 mg.kg^{-1} and a level of 2.5 % was given. Table 4 and the attached statistical analysis indicate a significant interaction effect between the type and level of fertilizer added to the studied soils on the concentration of available nitrogen during the incubation periods. The highest concentration of available nitrogen for all incubation periods in sandy mixed soil (41.19, 56.14, 91.82, and 86.20 mg.kg^{-1} soil respectively) and clayey soil (53.72, 70.87, 143.51, and 104.44 mg.kg^{-1} soil) respectively.

Organic manure gave the lowest content of available nitrogen for all incubation periods in the soil (Table 4). It indicates the significant role of chitosan and organic manure in increasing the availability of nutrients in the soil, as well as the role of chitosan in preserving nitrogen from loss and volatilization in the soil with increased application period, which is consistent with the findings of Behboudi [5]. The triadic interaction between fertilizer type, level, and Organic Manure level had a significant effect on available nitrogen.

Table 4: Effect of interaction between fertilizer type and levels of organic manure Addition (%) on Available Nitrogen Concentration (mg N.kg^{-1} soil) for all incubation periods and study soils

Period Incubation Days	Fertilizer Level (mg.kg^{-1} soil) NPK-Chitosan	Silty Clay Soil		Sandy Loam Soil	
		Organic Manure (%)		Organic Manure (%)	
		0	2.5	0	2.5
7	500	21.22	25.01	16.61	18.25
	1000	33.96	38.40	23.84	26.54
	2000	49.07	53.72	36.96	41.19
	RLSD	n.s		1.112**	
14	500	33.85	39.44	23.93	29.39
	1000	48.28	54.70	35.26	42.28
	2000	64.53	70.87	46.61	56.14
	RLSD	n.s		0.748**	
28	500	53.46	66.25	39.21	49.37
	1000	72.70	92.24	54.91	69.44
	2000	103.26	143.51	76.85	91.82
	RLSD	1.528**		1.253**	
56	500	37.81	49.70	32.40	41.08
	1000	52.92	66.97	46.53	58.13
	2000	88.82	104.44	69.33	86.20
	RLSD	0.884**		0.844**	

RLSD**= Indicate that there are significant differences between the coefficients at a significant level ($P \leq 0.001$) for the levels of fertilizer and the levels of Organic Manure in the nitrogen readiness of the two study soils.

Most of the incubation periods (14, 28, and 56 days), except for the 7-day incubation period (Tables 5 and 6) for both studied soils (Silty Clay and Sandy Loam). The treatment with NPK fertilizer at a level of 2000 mg.kg^{-1} and an organic manure level of 2.5% higher values with significant differences than the other treatments. The values were 99.07 and 60.30 mg.kg^{-1} soil for the 14-day incubation period in silty clay and sandy loam soils respectively, in sequential order. Similarly, the treatment with NPK fertilizer coated with chitosan at a ratio of 1:3, at a level of 2000 mg.kg^{-1} and an Organic manure level of 2.5 %, gave higher values during the 28 and 56-day incubation periods, which were 192.20, 136.40 mg.kg^{-1} for 28 days silty clay and sandy loam soils respectively and 137.60, 124.00 mg.kg^{-1} for 56 days silty clay and sandy loam soils respectively. Comparing these values with the treatment using NPK fertilizer alone for the same incubation periods (28 and 56 days), the values were 79.37, 64.33 mg.kg^{-1} for 28 days silty clay and sandy loam soils respectively and 69.87 53.40mg.kg^{-1} mg.kg^{-1} for 56 days silty clay and sandy loam soils respectively. It can be observed that the addition of chitosan to NPK fertilizer in a coated form caused an increase of 142.15%, 96.93%, 112.03% and 132.20% in succession. Following. in efficiency was the treatment with NPK fertilizer mixed with chitosan at a ratio of 1:3, at a level of 2000 mgkg^{-1} and an Organic Manure level of 2.5 % (Tables 5 and 6). It confirms the importance and necessity of using chitosan as a slow-release fertilizer to increase nitrogen availability in the soil.

Furthermore, it is noteworthy that the 56-day incubation period the highest values of available nitrogen compared to the other incubation periods, indicating the continuous release of nitrogen from the chitosan-coated or mixed NPK fertilizer, thus maintaining and reducing losses resulting from the addition of chemical fertilizers to the soil.

Table 5: The Effect of type and level of fertilizer, and Organic Manure addition levels (%) on available nitrogen concentration in Silty Clay soil for incubation periods A7, B14, C28, and D56 days.

Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan			Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan		
		500	1000	2000			500	1000	2000
Coated 1:1	0	11.60	19.60	30.80	Coated 1:1	0	16.80	35.60	44.80
	2.5	13.60	22.20	35.33		2.5	26.40	41.00	48.27
Coated 1:2	0	19.20	28.80	42.00	Coated 1:2	0	30.00	40.40	55.20
	2.5	22.67	32.40	44.40		2.5	31.20	46.00	62.53
Coated 1:3	0	21.60	37.60	50.43	Coated 1:3	0	50.00	57.60	72.40
	2.5	27.13	41.60	56.07		2.5	53.47	61.27	76.23
Mixing 1:1	0	13.20	25.47	37.97	Mixing 1:1	0	18.00	38.00	46.00
	2.5	15.60	26.53	40.30		2.5	30.00	45.80	56.80
Mixing 1:2	0	23.67	33.60	50.47	Mixing 1:2	0	32.80	41.60	65.20
	2.5	27.67	36.00	54.20		2.5	35.60	51.47	70.40
Mixing 1:3	0	27.60	40.20	57.23	Mixing 1:3	0	52.80	60.80	80.00
	2.5	29.67	47.60	61.13		2.5	52.80	65.83	82.80
NPK	0	31.68	52.44	74.62	NPK	0	36.57	63.99	88.09
	2.5	38.74	62.46	84.58		2.5	46.58	71.50	99.07
A	RLSD	n.s			B	RLSD	2.665^{**}		
Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan			Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan		
		500	1000	2000			500	1000	2000
Coated 1:1	0	40.40	65.20	87.80	Coated 1:1	0	32.00	41.60	76.00
	2.5	58.80	81.60	146.00		2.5	44.40	51.60	79.60
Coated 1:2	0	60.80	82.40	142.40	Coated 1:2	0	41.60	54.40	99.60
	2.5	79.20	113.60	192.40		2.5	57.60	67.60	122.60
Coated 1:3	0	76.80	91.20	142.40	Coated 1:3	0	49.20	75.20	124.40
	2.5	95.20	136.40	192.20		2.5	61.20	98.00	137.60
Mixing 1:1	0	37.13	60.40	81.43	Mixing 1:1	0	27.60	39.60	63.20
	2.5	44.80	66.40	119.20		2.5	37.60	49.60	84.00
Mixing 1:2	0	56.00	76.40	100.27	Mixing 1:2	0	39.20	50.80	84.80
	2.5	63.60	90.00	134.80		2.5	52.00	65.60	107.20
Mixing 1:3	0	71.60	86.97	137.80	Mixing 1:3	0	47.60	68.00	113.20
	2.5	80.40	100.40	156.40		2.5	58.00	82.80	130.80
NPK	0	31.47	46.37	65.11	NPK	0	27.47	40.87	60.53
	2.5	41.76	57.30	79.37		2.5	37.10	53.57	69.87
C	RLSD	4.042^{**}			D	RLSD	2.338^{**}		

RLSD= Indicate that there are significant differences between the coefficients at a significant level ($P \leq 0.001$) for the levels type of fertilizer and the levels of Organic Manure in the nitrogen readiness of the two study soils.**

Table 6: The Effect of type and level of fertilizer, and Organic Manure addition levels (%) on available nitrogen concentration in sandy loam soil for incubation periods A7, B14, C28, and D56 days

Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan			Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan		
		500	1000	2000			500	1000	2000
Coated 1:1	0	10.10	16.40	25.00	Coated 1:1	0	28.80	20.00	25.00
	2.5	8.90	18.20	26.23		2.5	32.80	23.20	26.23
Coated 1:2	0	14.13	20.00	30.40	Coated 1:2	0	38.40	24.00	30.40
	2.5	14.80	24.40	40.00		2.5	43.60	30.80	40.00
Coated 1:3	0	17.60	26.40	39.20	Coated 1:3	0	40.80	32.00	39.20
	2.5	21.20	31.60	44.00		2.5	51.80	37.60	44.00
Mixing 1:1	0	11.20	17.30	27.17	Mixing 1:1	0	41.60	32.00	27.17
	2.5	12.00	17.60	30.30		2.5	52.80	40.40	30.30
Mixing 1:2	0	15.67	23.90	36.40	Mixing 1:2	0	52.00	40.80	36.40
	2.5	17.30	24.40	40.27		2.5	6.40	46.80	40.27
Mixing 1:3	0	18.80	31.33	44.23	Mixing 1:3	0	60.40	47.60	44.23
	2.5	22.40	33.27	47.20		2.5	77.60	57.60	47.20
NPK	0	28.77	31.57	56.30	NPK	0	64.30	50.40	56.30
	2.5	31.17	36.30	60.30		2.5	74.20	59.57	60.30
A	RLSD	n.s			B	RLSD	1.979**		
Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan			Fertilizer Type	Organic Manure	Fertilizer Level (mg/kg soil) NPK-Chitosan		
		500	1000	2000			500	1000	2000
Coated 1:1	0	32.40	45.20	74.80	Coated 1:1	0	28.80	37.60	66.00
	2.5	46.80	66.80	88.80		2.5	35.60	43.60	76.40
Coated 1:2	0	45.60	67.60	100.40	Coated 1:2	0	35.60	42.97	90.00
	2.5	60.80	88.00	119.20		2.5	42.80	60.00	98.40
Coated 1:3	0	53.20	80.40	121.60	Coated 1:3	0	43.20	65.67	100.40
	2.5	70.80	97.60	136.40		2.5	52.00	71.20	124.00
Mixing 1:1	0	23.30	43.20	44.80	Mixing 1:1	0	24.00	34.80	50.40
	2.5	33.20	49.60	59.60		2.5	30.00	50.40	70.00
Mixing 1:2	0	35.60	45.20	64.80	Mixing 1:2	0	31.20	45.60	62.87
	2.5	41.60	57.20	82.00		2.5	45.20	57.20	87.60
Mixing 1:3	0	58.00	62.40	80.00	Mixing 1:3	0	43.60	62.80	75.20
	2.5	58.00	74.80	92.40		2.5	53.60	78.00	93.60
NPK	0	26.40	40.40	51.53	NPK	0	20.37	36.27	40.43
	2.5	34.40	52.07	64.33		2.5	28.37	46.53	53.40
C	RLSD	3.314**			D	RLSD	2.233**		

RLSD= Indicate that there are significant differences between the coefficients at a significant level ($P \leq 0.001$) for the levels type of fertilizer and the levels of Organic Manure in the nitrogen readiness of the two study soils.**

These results are consistent with the findings of Ayu Puspita [20], which emphasized the importance of using chitosan with chemical NPK fertilizers to minimize fertilizer loss and maximize benefits. Using chitosan in combination with chemical fertilizers.

Enhances the availability of nutrients to plants over extended periods. These results align with the findings of [4, 19, and 21].

CONCLUSIONS

NPK-Chitosan increased nitrogen availability with addition of organic manure and Fertilizer NPK-Chitosan can be used in calcareous soils, as slow-release fertilizer when it is mixed or coated with mineral NPK fertilizer.

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كفاءة الاسمدة المحضرة بطيئة التحرر (NPK-Chitosan) والمادة العضوية وفترات حضن على جاهزية النتروجين لتربتين كلسية*

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الملخص

أجريت الدراسة في تجربة معملية لدراسة كفاءة الأسمدة النيتروجينية–الشيتوزان المشتق من قشور الجمبري بنسبة **1:3** (**NPK-Chitosan**) (طلاء وخلط) عند أربعة مستويات سماد (**0**، **500**، **1000** و**2000** ملغم كغم$^{-1}$ تربة) ومستويين من المواد العضوية (**0** و**2.5**٪) من حيث جاهزية النيتروجين في نوعين من التربة (الطينية غرينية والمزيجة الرملية مقارنة بالأسمدة النيتروجينية المعاملة المقارنة (التجارية) واحتضنت لمدة أربع فترات (**7**، **14**، **28**، **56** يوما) لتقييم جاهزية النيتروجين. وأظهرت النتائج أن إضافة الأسمدة والمواد العضوية زادت بشكل كبير من جاهزية النيتروجين في كلتا التربة. الأسمدة **NPK-Chitosan**، مع نسبة معاملات تغليف بنسبة **1:3** وخلط **1:3**، تفوقت على معاملة السيطرة (الأسمدة NPK وحدها) في زيادة النيتروجين الجاهز. كما أظهرت النتائج تأثيرا كبيرا لمستويات الأسمدة على زيادة تركيز النيتروجين في كلتا التربتين. زاد التركيز مع ارتفاع مستوى الأسمدة(**2000** ملغم.كغم$^{-1}$ تربة) محققا أعلى قيم نيتروجين لكل من التربة، **90.9** و**91.47** ملغم .كغم$^{-1}$ تربة، على التوالي، مع اختلاف كبير مقارنة بمستويات التربة **500** و**1000** ملغم كغم$^{-1}$ تربة. أضافة الى ذلك، يتجاوز مستوى التربة **1000** ملغم كغم$^{-1}$ تربة على الأسمدة النيتروجينية (معاملة المقارنة). بينت النتائج عن تأثير معنوي بين نوع ومستوى السماد على تركيز النيتروجين الجاهز. الأسمدة **NPK-Chitosan** بنسبة تغليف **1:3** على مستوى **2000** ملغ كغم$^{-1}$ تربة تفوقت المعاملات الأخرى، بلغت أعلى تركيزاً للنيتروجين من **129.73** و**898** ملغم كغم$^{-1}$ تربة لكلتا التربتين، على التوالي. وقد ازدادت جاهزية العنصر مع زيادة مستويات الأسمدة المضافة واضافة المادة العضوية وانخفضت مع زيادة مدة الحضن.

الكلمات الدالة: كيتوسان، نيتروجين جاهز، مادة عضوية، ترب كلسية

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