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Effect of different levels and sources of nitrogen on chemical properties of sodic soil under spinach cultivation

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Abstract
The present study entitled, "Effect of different levels and sources of nitrogen on chemical properties of sodic soil under spinach cultivation" was carried out at research farm of Department of Soil Science, MPKV, Rahuri during *summer* 2024. The study revealed that, among different levels (40, 80 and 100 kg N ha^{-1}) of urea and ammonium sulphate on soil pH, electrical conductivity, organic carbon, calcium carbonate, available phosphorous, available potassium and available micronutrients were found non-significant. But for available nitrogen treatment T_7 (100 kg N ha^{-1} ammonium sulphate) has highest available nitrogen (167 kg ha^{-1}) in soil which is at par with 80 kg N ha^{-1} ammonium sulphate-T_6 (163 kg ha^{-1}), 80 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea-T_{11} (162 kg ha^{-1}) and 100 kg N ha^{-1} urea-T_4 (159 kg ha^{-1}) over all other treatments.

Keywords: Nitrogen levels and sources, urea, ammonium sulphate, nano urea, sodic soil, uptake, spinach, yield

Introduction

Spinach (*Spinacia oleracea*) is an annual leafy green vegetable plant native to central and western Asia. It is of the order *Caryophyllales*, family Amaranthaceae (Swarup, 2014) [14]. Spinach leaves are valued for their medicinal properties and it is used in inflammation, paralysis, headache and remedy for disease of spleen and liver, it also acts as mild lacerative besides other medicinal values, it supplies most of the nutrients in which other foods are deficient. It is used as a fresh vegetable for cooking and also as a salad form. It contains 86.49% of moisture, 0.7 g of fibre, 3.4 g of protein, 2.2 g of minerals, 6.5 g of carbohydrates, 0.5 g of riboflavin, 380 mg of calcium, 16.2 mg of iron, 0.26 g of thiamine, 9770 IU of vitamin A, 70 mg of vitamin C and 100 mg of edible portion (Swarup, 2014) [14]. Salinity represents one of the most pressing threats to agricultural productivity on a global scale. Approximately 10% of the Earth's terrestrial area and nearly half of all irrigated agricultural land are facing negative impacts by saline soils (Ruan *et al*., 2010) [13]. When the nitrogenous fertilizers are added to soil, they are undergoing ammonical fixation in soil and rendered unavailable to the plant. In addition to these the nitrogen from fertilizers is also lost from soil-water system through denitrification, volatilization and leaching. It is observed that utilization of urea applied to soil is not as effective as when the urea is supplied to plants through foliage by soil application. When nano-urea is applied on surface of leaves there will not be any fixation losses thus, increases NUE. The application of nano-urea during key developmental stages of crops significantly enhances nitrogen utilization, resulting in improved yield and produce quality compared to traditional urea fertilizers. Nano urea (in liquid form) comprises nanoscale nitrogen particles, which offer a surface area almost 10,000 times greater than that of conventional granular urea. Upon foliar application, the nano-formulation is readily absorbed through the leaf surface due to its ultrafine particle size and favourable surface characteristics, ensuring more efficient nitrogen delivery to plant tissues (Kulal, 2023) [8]. In view to above, present study is undertaken to study effect of different levels and sources of nitrogen on chemical properties of sodic soil under spinach cultivation.

Materials and Methods

The experiment was conducted during *summer* 2024 at Post Graduate Institute Farm, MPKV, Rahuri. Geographically, the experimental fixed site lies at 19º34' North latitude and 74º64' East longitude and at an altitude of 511m above mean sea level. The tract is lying on eastern site of Western ghat and falls under rain shadow area. The experiment was carried out using All green variety seeds of spinach, sown in 2024 at a spacing of 30 cm x 10 cm. Randomly selected healthy and uniform plants of spinach (All green) were selected for the study.

Collection and analysis of soil samples

In order to study the chemical properties of experimental soil, a representative composite soil samples were collected from each treatment from the experimental location that is Post Graduate Institute Farm, MPKV, Rahuri. Soil samples were collected from experimental location twice, first before the application of fertilizers and next after harvesting of crop. Soil samples from a depth of 0-15 cm were collected by adopting quartering method for all the treatments and replications. Soils were collected in polythene bags which were dried in the shade for processing. The air-dried soil samples were ground in wooden mortar and pestle and sieved through 2.0 mm sieve and were used for determination of chemical properties of soil. For organic carbon and calcium carbonate soil was sieved from aggregate stability, soil was sieved from 0.5 mm sieve. The analysis was done by using standard methods used for analysis of chemical properties of soil.

Experimental Details

The field experiment was laid out in RBD with eleven treatments and three replications. The treatments were absolute control (T_1), 40 kg N ha^{-1} through urea (T_2), 80 kg N ha^{-1} through urea (T_3), 100 kg N ha^{-1} through urea (T_4), 40 kg N ha^{-1} through ammonium sulphate (T_5), 80 kg N ha^{-1} through ammonium through urea sulphate (T_6), 100 kg N ha^{-1} through ammonium sulphate (T_7), 40 kg N ha^{-1} through urea + 0.2% foliar spray of nano urea (T_8), 80 kg N ha^{-1} through urea + 0.2% foliar spray of nano urea (T_9), 40 kg N ha^{-1} through ammonium sulphate + 0.2% foliar spray of nano urea (T_{10}), 80 kg N ha^{-1} through ammonium sulphate + 0.2% foliar spray of nano urea (T_{11}). The statistical analysis was done by procedure suggested by Panse and Sukhatme (1989) [12].

Results and Discussion

The research was conducted at Post Graduate Institute Research Farm (Inceptisol), MPKV, Rahuri during *summer*, 2024-25.

Effect of different levels and sources of nitrogen on chemical properties of soil at harvest of spinach

Soil pH, Electrical Conductivity, Organic Carbon and Calcium Carbonate

Soil pH, electrical conductivity, organic carbon and calcium carbonate as influenced by different levels and sources of nitrogen given in Table 1. The results revealed that, there was no significant change in soil pH, electrical conductivity, organic carbon and calcium carbonate as the result of different treatments.

The pH of the soil ranged from 8.36 to 8.62 across treatments. However, slight decrease in pH was noticed as compared to initial stage (8.78). The highest soil pH (8.62) was observed in absolute control-T_1 and the lowest soil pH (8.36) in treatment 80 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea-T_{11}. The decrease in soil pH might be attributed to acidifying effect of ammonium sulphate on soil due to the production of hydrogen ions during nitrification of ammonium. Results are supported by Korwar *et al*., (2006) [7]; Marathe *et al*., (2017) [10]. It is also may be due to higher buffering capacity of clayey soils (Biswas *et al*., 1971) [3]. The similar line of results was reported earlier by Bhavana *et al*., (2020) [2]; Heinrichs *et al*., (2012) [4]; Huang *et al*., (2016) [5]; Pandey *et al*., (2018) [11].

There was no statistically significant change in electrical conductivity of soil was observed. The electrical conductivity was ranged from 1.36 to 1.90 dS m^{-1}. However, slight increase in electrical conductivity was found at the time of harvest as compared to initial (1.32 dS m^{-1}). The increase in electrical conductivity with higher N levels might be due to addition of fertilizers, especially ammonium sulphate, which increased the soluble salt concentration in the soil. Electrical conductivity is a direct indicator of soil salinity, and the accumulation of ions such as NH_4^+, SO_4^{2-}, and NO_3^- from fertilizers led to increase. The results are in accordance with Kamble and Todmal (2020) [6] and Bhavana *et al*., (2020) [2].

For organic carbon also similar results found as above. The organic carbon of the soil ranged from 0.42% to 0.54%. The highest soil organic carbon (0.54%) was observed in treatment 80 kg N ha^{-1} ammonium sulphate-T_7 and the lowest organic carbon (0.42%) in absolute control (T_1). The slight increase in organic carbon content with nitrogen application as compared to initial value (0.46%) could be attributed to enhanced plant growth, resulting in more organic matter incorporated to the soil in the form of root exudates, plant roots and decaying residues. The ammonium sulphate and nano urea treatments might have stimulated microbial biomass, which contributed to increased organic carbon. The results were corroborated with Bhavana *et al*., (2020) [2].

Similarly, there was no significant difference in in calcium carbonate of soil was observed in different treatments. However, there was slight decrease in calcium carbonate was noticed. The calcium carbonate was found highest (12.00%) in absolute control-T_1 and lowest calcium carbonate (10.53%) was recorded in treatment 80 kg N ha^{-1} ammonium sulphate-T_7. The slight decrease in calcium carbonate content as compared to initial value (12.01%) primarily due to the acidifying effect on soil. During the nitrification process, ammonium ions (NH_4^+) from ammonium sulphate converted to nitrate (NO_3^-), released hydrogen ions (H^+) in the soil. These hydrogen ions reacted with calcium carbonate, led to its dissolution into calcium ions (Ca^{2+}), water, and carbon dioxide. This reaction reduced the measurable calcium carbonate content. Additionally, the released Ca^{2+} ions may be leached from the soil profile, especially under irrigation, further decreased the residual carbonate levels. The similar results were reported earlier by Mairan *et al*., (2016) [9].

Effect of Different Levels and Sources of Nitrogen on Available Nitrogen, Phosphorous and Potassium Status of Soil

The available Nitrogen, Phosphorous and Potassium content of soil as influenced by different levels and sources of nitrogen given in Table 2.

The treatment 80 kg N ha⁻¹ ammonium sulphate-T_7 have highest available nitrogen (167 kg ha^{-1}) in soil which is at par with 80 kg N ha^{-1} ammonium sulphate-T_6 (163 kg ha^{-1}), 80 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea-T_{11} (162 kg ha^{-1}) and 100 kg N ha^{-1} urea-T_4 (159 kg ha^{-1}) over all other treatments. The lowest available nitrogen (148 kg ha^{-1}) was recorded in absolute control-T_1. The significant increase in available nitrogen in soil as compared to initial value (170 kg ha^{-1}) might be due to application of ammonium sulphate which supplied nitrogen in the ammonical (NH_4^+) form. It slightly acidified the soil, which helped in retaining NH_4^+ ions and improves microbial nitrogen mineralization. Nano urea further improved nitrogen use efficiency, reducing losses and improved assimilation. The results were similar with Huang *et al*., (2016) [5]; Adebayo *et al*., (2017) [1] and Teressa *et al*., (2024) [15].

There was non significant change in available phosphorous and potassium content. The available phosphorus ranged from 8.78 kg ha^{-1} to 11.60 kg ha^{-1}. The highest soil available phosphorus (11.60 kg ha^{-1}) was observed in treatment 40 kg N ha^{-1} urea-T_2 and the lowest soil available phosphorus (8.78 kg ha^{-1}) recorded in treatment absolute control-T_1. However, a slight decrease in soil available phosphorus content at the harvest stage compared to the initial was observed and it might be due to plant uptake and nutrient transformation in the soil. The results were supported by the findings Bhavana *et al*., (2020) [2]. The available potassium content was ranged from 353 kg ha^{-1} to 376 kg ha^{-1}. The highest soil available potassium (376 kg ha^{-1}) was observed in treatment 40 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2%-T_{10} and the lowest in treatment absolute control-T_1 (353 kg ha^{-1}). The results are in accordance with Bhavana *et al*., (2020) [2]. The slight decrease in available potassium content as compared to initial value (377 kg ha^{-1}) was observed.

Effect of Different Levels and Sources of Nitrogen on Available Micronutrients Status of Soil

The results pertaining to the effect of different levels and sources of nitrogen on DTPA micronutrients (Iron, Manganese, Copper, Zinc) in soil presented in Table 3. The results pertaining to DTPA extractable micronutrients was found non-significant with respect to all the treatments.

The DTPA iron content in soil varied from 3.69 mg kg^{-1} to 4.54 mg kg^{-1} at the harvest of crop. The highest soil DTPA iron (4.54 mg kg^{-1}) was observed in treatment 80 kg N ha^{-1} ammonium sulphate-T_7 and the lowest in treatment absolute control-T_1 (3.69 mg kg^{-1}). The DTPA extractable copper content in soil varied from 2.17 mg kg^{-1} to 2.33 mg kg^{-1} after the harvest of crop. The highest soil DTPA extractable copper (2.33 mg kg^{-1}) was observed in treatment 80 kg N ha^{-1} ammonium sulphate-T_7 and the lowest (2.17 mg kg^{-1}) in treatment absolute control-T_1. The DTPA extractable manganese content in soil varied from 12.39 mg kg^{-1} to 15.71 mg kg^{-1} after the harvest of crop. The highest DTPA extractable manganese (15.71 mg kg^{-1}) was observed in treatment 80 kg N ha^{-1} ammonium sulphate-T_7 and the lowest in treatment absolute control-T_1 (12.39 mg kg^{-1}). The DTPA extractable zinc content in soil varied from 0.57 mg kg^{-1} to 0.65 mg kg^{-1} after the harvest of crop. The highest DTPA extractable zinc (0.65 mg kg^{-1}) was observed in treatment 80 kg N ha^{-1} ammonium sulphate-T_7 and the lowest in treatment absolute control-T_1 (0.57 mg kg^{-1}).

Table 1: Effect of different levels and sources of nitrogen on pH, EC, OC and $CaCO_3$ content of soil at harvest of spinach

Tr. No.	Treatment details	pH	EC (dS m^{-1})	OC (%)	$CaCO_3$ (%)
T_1	Absolute control	8.62	1.36	0.42	12.00
T_2	40 kg N ha^{-1} urea	8.55	1.51	0.43	11.96
T_3	80 kg N ha^{-1} urea	8.50	1.58	0.45	11.91
T_4	100 kg N ha^{-1} urea	8.45	1.62	0.51	11.88
T_5	40 kg N ha^{-1} ammonium sulphate	8.42	1.55	0.43	10.69
T_6	80 kg N ha^{-1} ammonium sulphate	8.38	1.81	0.49	10.59
T_7	100 kg N ha^{-1} ammonium sulphate	8.40	1.90	0.54	10.53
T_8	40 kg N ha^{-1} urea + foliar spray of 0.2% nano urea	8.52	1.50	0.45	12.00
T_9	80 kg N ha^{-1} urea + foliar spray of 0.2% nano urea	8.47	1.52	0.51	11.84
T_{10}	40 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea	8.49	1.63	0.44	11.12
T_{11}	80 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea	8.36	1.78	0.52	10.57
	S. Em (±)	0.26	0.10	0.03	0.87
	C.D (5%)	NS	NS	NS	NS
	Initial	8.78	1.32	0.46	12.01

Table 2: Effect of different levels and sources of nitrogen on available N, P and K content of sodic soil at harvest of spinach

Tr. No.	Treatment details	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Absolute control	143^{b}	8.78	353.0
T_2	40 kg N ha^{-1} urea	150^{ab}	11.60	374.0
T_3	80 kg N ha^{-1} urea	154^{ab}	9.97	367.0
T_4	100 kg N ha^{-1} urea	159^{ab}	9.78	365.0
T_5	40 kg N ha^{-1} ammonium sulphate	156^{ab}	11.45	370.0
T_6	80 kg N ha^{-1} ammonium sulphate	163^{ab}	9.43	366.0
T_7	100 kg N ha^{-1} ammonium sulphate	167^{a}	9.15	362.0
T_8	40 kg N ha^{-1} urea + foliar spray of 0.2% nano urea	153^{ab}	11.33	359.0
T_9	80 kg N ha^{-1} urea + foliar spray of 0.2% nano urea	154^{ab}	10.15	369.0
T_{10}	40 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea	152^{ab}	11.25	356.0
T_{11}	80 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea	162^{ab}	9.12	377.0
	S. Em (±)	4.63	0.72	14.99
	C.D (5%)	13.66	NS	NS
	Initial	170	11.88	377.00

Table 3: Effect of different levels and sources of nitrogen on DTPA extractable micronutrients status of soil at harvest of spinach

Tr. No.	Treatment details	DTPA extractable micronutrients (mg kg^{-1})			
		Fe	Cu	Mn	Zn
T_1	Absolute control	3.69	2.17	12.39	0.57
T_2	40 kg N ha^{-1} urea	4.28	2.19	14.54	0.59
T_3	80 kg N ha^{-1} urea	4.32	2.25	14.64	0.61
T_4	100 kg N ha^{-1} urea	4.43	2.20	14.77	0.58
T_5	40 kg N ha^{-1} ammonium sulphate	4.28	2.23	14.57	0.60
T_6	80 kg N ha^{-1} ammonium sulphate	4.30	2.25	14.97	0.61
T_7	100 kg N ha^{-1} ammonium sulphate	4.54	2.33	15.71	0.65
T_8	40 kg N ha^{-1} urea + foliar spray of 0.2% nano urea	4.47	2.28	15.14	0.62
T_9	80 kg N ha^{-1} urea + foliar spray of 0.2% nano urea	4.53	2.31	15.45	0.64
T_{10}	40 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea	4.51	2.27	15.28	0.62
T_{11}	80 kg N ha^{-1} ammonium sulphate + foliar spray of 0.2% nano urea	4.46	2.26	15.07	0.61
	S. Em (±)	0.18	0.09	0.72	0.05
	C.D (5%)	NS	NS	NS	NS
	Initial	4.52	2.25	15.09	0.61

Conclusion

Soil pH, EC, organic carbon, calcium carbonate, available phosphorus, potassium and DTPA extractable micronutrients were found to be non-significant. The significantly highest available nitrogen was recorded by the application of 100 kg N ha^{-1} through ammonium sulphate. The application of 80 kg N ha^{-1} through ammonium sulphate + 0.2% nano urea two foliar sprays at 35 and 50 days after sowing along with general recommended dose of P and K 40:40 P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} FYM to spinach in sodic soil was found beneficial for increase in chemical properties of soil and obtaining higher economic returns from spinach in sodic soil.

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