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ISOTOPE-AIDED STUDIES ON THE NITROGEN UTILIZATION AND YIELD OF LENTIL AS INFLUENCED BY IRRIGATION REGIMES IN A SALT-AFFECTED SOIL

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Field experiments were conducted for two consecutive years to study the nitrogen utilization and yield of lentil as influenced by different irrigation regimes in the salt-affected soils of Bajoa series (Typic Haplaquept) in Satkhira, Bangladesh. The split-plot design experiments included two sources of irrigation water *viz.* (i) Stored lake water (LW) and (ii) Tube-well water (TW) in the main-plots and three irrigation regimes such as (i) W_0 - no irrigation, (ii) W_1 - one irrigation of 5 cm, and (iii) W_2 - two irrigations of 5 cm each in the sub-plots. Sources of irrigation water had no significant effect on the yield and nitrogen utilization by lentil although irrigation increased the lentil yield in the first year, but it was considerably lower compared to average national yield. During the second year, the yield, total N uptake and biological nitrogen fixation by lentil increased considerably due to the use of *Rhizobium* inoculated seeds. The extent of fertilizer N uptake and N utilization were, more or less similar in both the years. The A-value concept provided a unique opportunity to quantify the amount of nitrogen fixed by a legume crop under the adverse condition of salinity.

Key words: N^{15} isotope, Irrigation, N-fixation, Salt-affected soil.

Introduction

It has recently been reported that out of 2.85 million hectares of coastal and offshore areas, 0.833 million hectares of land are affected by different degrees of salinity in Bangladesh [1]. The severity of salinity problems in Bangladesh increases with the desication of soil. The minimum salinity of 0.5 dSm^{-1} was recorded at some places in the month of October at the end of monsoon season due to dilution effects, while the maximum of 68.2 dSm^{-1} was recorded in the month of May at the end of dry season [2]. Transplanted rice is grown as a sole crop on the heavier saline soils of low lying areas during the wet season (June-October). Crops are not generally cultivated during the dry winter season due to lack of irrigation facilities and proper management practices of the salt-affected soils. Several winter crops like groundnut, lentil, chickpea, sesame, wheat and barley are, however, grown on a limited scale in scattered locations of higher elevation. There are usually two sources of water in the saline area which may be used for winter crop cultivation. One is saline water (EC 2.5-4.0 dSm^{-1}) available in the rivers, canals and surface dug out pond and the other is deep tube-well water (EC 0.70 dSm^{-1}) which is less saline but expensive for the poor farmers.

High sodicity and high pH conditions of salt-affected soils encourage losses of applied nitrogen through volatilization. The less organic matter content of these soils further accentuates N deficiency in crop grown in these soils [3]. There are reports of N accumulation and N fixation by nodulating crops grown in normal soils [4-7]. Adequate information are not available on the cultivation of winter crops in the saline soils of Bangladesh. Moreso, N transformation and its utilization by crops under saline conditions have not been studied much. Nitrogen utilization by wheat in the salt-affected soil has been reported by Rahman *et al.* [8]. Experiments were, therefore, conducted to study the yield and water requirement of lentil using the available sources of irrigation water in the salt-affected soils. Nitrogen utilization and biological nitrogen fixation by these crops were also studied using N^{15} - isotope.

Materials and Methods

Field experiments were conducted during 1987-88 and 1988-89 with lentil as test crop in the 'Typic Haplaquept' clay soils of Bajoa series at the Benerpota Experimental Farm of Bangladesh Water Development Board, Satkhira. Some physico-chemical properties of the experimental soil are presented in Table 1. The experiments were conducted in a split-plot design with two available sources of irrigation water *viz.* (i) stored lake water (LW) and (ii) tube-well water (TW) in the main-plots. The sub-plot treatments were the irrigation levels *viz.* (i) no irrigation (W_0), (ii) irrigation of 5 cm at 5 weeks after planting (W_1) and (iii) first irrigation of 5 cm at 5 weeks after planting + later irrigations of 5 cm each at IW/CPE ratio of 0.5 (W_2), where, IW is the amount of irrigation water (5 cm here) and CPE is the cumulative pan evaporation. The EC of lake water varied from 2.5 to 4.0 dSm^{-1} during the crop growing season, whereas that of tube-well water remained unchanged (0.70 dSm^{-1}). All the treatments had four replications. Each irrigation sub-plot (2m x 5m) was sub-divided into isotope (2m x 1m) and yield (2m x 4m) sub-plots. The main-plots and the split plots were separated from each other by a buffer zone of 1m and 0.5m, respectively.

Fertilizers were applied once in each growing season @30 kg N, 35 kg P, 50 kg K and 40 kg S, ha^{-1} as urea, triple super phosphate, muriate of potash and gypsum, respectively as basal dose during final land preparation. N^{15} enriched urea with 3% atom excess were applied in the isotope sub-plots. Lentil seeds (*Lens culinaris* Medik, cv. L-5) were inoculated with *Rhizobium* in 1988 only. Irrigation was applied from the nearby lake and tube-well according to the treatments.

Plant samples were collected immediately before the harvest from N^{15} sub-plots for total N and N^{15} analyses. N^{15} analyses were carried out at the Seibersdorf Laboratory of IAEA. Seed and straw yields were recorded after harvest of the crop. Total and fertilizer N, percent N derived from fertilizer (Ndff) and percent utilization of applied N in plants were computed from percent total N and N^{15} atom excess data [9]. The amount of N_2 fixed by lentil under field conditions were computed from the differences of A-values of lentil and the reference crop (wheat) grown in the same field side by side using the method of Fried and Middleboe [10].

Results and Discussion

Seed and straw yields. The data on seed and straw yields of lentil as influenced by sources of water and irrigation regimes during 1987-88 and 1988-89 are presented in Table 2. Results indicated that the sources of water had no effect on the yield of lentil in 1987-88. Irrigation with tube-well water apparently increased the seed yield as compared with lake water but the differences were not statistically significant. The electrical conductivity (EC) values of lake water increased with time during November - March (from 2.5 to 4.5 dSm^{-1}), whereas the same of tube-well water remained almost constant (0.70 dSm^{-1}). The lentil crop when irrigated with lake water started dying resulting into lesser number of plants per m^2. Moreover, hot weather persisted in this season and the soil water evaporation was high. Soil salinity increased considerably thus, the yield, in general, was very low in plots irrigated with both lake and tubewell water. Lentil, in general, is cultivated without any irrigation and is non-responsive to irrigation. Because of the high evaporative demand, the average effects of irrigation regimes irrespective of sources of water, on both seed and straw yields of lentil were found significant. Seed yield was increased by 65% (288 kg ha^{-1}) in W_1 and by 121% (387 kg ha^{-1}) in W_2 treatment. The interaction effect of sources of water and irrigation regimes was also significant. The highest seed and straw yields of 410 and 1252 kg ha^{-1}, respectively were observed in plots receiving two irrigations with tube-well water. In contrast to 1987-88, results of 1988-89 experiment indicated that neither the seed nor the straw yield of lentil were significantly influenced by either the sources of water or the irrigation regimes. Seed yield decreased in the irrigated plots - the decrease was more prominent in the plots irrigated with lake water of higher EC values. Irrigation with tube-well water produced 598 kg ha^{-1} seed yield which was not significantly different from that obtained by irrigation with lake water. Similar results were obtained in case of straw yield also. Irrigation regimes also did not have any influence on the yield of lentil. The pan evaporation was much lower in the growing season (257 mm) compared to that of 1987-88 (318 mm). The water depletion in the soil profile (0-60 cm) ranged between 88 and 119 mm in different treatments in 1987-88 and, 66 and 87 mm in 1988-89. Irrigation with either sources of water decreased both seed and straw yields. This means that irrigation of lentil crop in the salt-affected soils may not be necessary. Generally, lentil is sensi-

TABLE 1. SOME PHYSICAL AND PHYSICO-CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOIL AT SATKHIRA.

Soil depths cm	Particle size distribution Sand %	Silt %	Clay %	Texture	Saturation water content %	Bulk density g cm^{-3}	pH	EC dSm^{-1}	CEC me%
00-15	23.1	34.2	42.7	Clay	41.5	1.32	6.9	8.60	16.2
15-30	12.5	38.4	49.1	Clay	44.5	1.29	6.7	2.50	16.5
30-45	13.1	34.5	52.4	Clay	43.0	1.36	7.0	2.70	17.2
45-60	10.5	23.1	66.4	Clay	44.5	1.36	7.1	2.90	15.8

Soil depths cm	Organic matter %	Total N %	Na^+	K^+	Ca^{++}	Mg^{++} (mel⁻¹)	Cl^-	HCO_3^-	SO_4	SAR
00-15	1.98	0.14	18.4	0.57	10.0	8.7	32.0	1.40	12.8	6.01
15-30	1.22	0.10	8.4	0.51	7.4	6.9	18.3	1.09	11.1	3.15
30-45	1.08	0.08	7.3	0.43	8.0	7.8	20.3	1.30	10.9	2.60
45-60	0.95	0.08	6.9	0.48	6.9	6.4	17.0	1.07	10.7	2.67

TABLE 2. EFFECTS OF SOURCES OF WATER AND IRRIGATION REGIMES ON THE SEED AND STRAW YIELDS OF LENTIL.

Treatment	Seed yield, kg ha^{-1}			Straw yield, kg ha^{-1}		
Sources of water irrigation regimes	LW*	TW*	Mean	LW	TW	Mean
1987-88						
W_0**	149	200	175c	464	555	510c
W_1**	283	293	288b	997	995	996b
W_2**	363	410	387a	1194	1252	1223a
Mean	265a	301a	–	885a	934a	–
1988-89						
W_0	608	628	618a	1571	1357	1464a
W_1	627	584	606a	1369	1256	1313a
W_2	527	582	555a	1339	1443	1391a
Mean	587a	598a	–	1426a	1352a	–

Figures followed by the same letter in a column or row of a parameter are not statistically different.

* LW = Lake water, TW = Tube-well water, ** W_0 = No irrigation.

W_1 = Irrigation of 5 cm at 5 weeks after planting, and W_2 = First irrigation of 5 cm at 5 weeks after planting + later irrigations of 5 cm at IW/CPE ratio of 0.5.

tive to excessive moisture condition. The salts dissolved in either lake or tube-well water contribute to higher mortality rate of the crop. If the lentil seeds are planted in time with optimum soil water, the roots proliferating below would be able to draw water from the sub-surface soil. In general, lentil yield was higher in 1988-89 compared with the previous year due to use of *Rhizobium* inoculated seeds. The cultivar used in these experiments is an advance line developed at the Bangladesh Agricultural Research Institute and has been reported to be moderately salt-tolerant. The native rhizobial population in the salt-affected soils is very low (0-18 per gram of dry soil) [6]. No record on survival of the inoculated organisms were, however, made.

N-uptake by lentil. Total and fertilizer N uptake, nitrogen derived from fertilizer (Ndff) and nitrogen utilization by lentil as influenced by sources of water and irrigation regimes for the two years are presented in Table 3. The sources of water had no significant effect on total and fertilizer N uptake, Ndff and N utilization by lentil. But irrigation significantly increased both total and fertilizer N uptake, Ndff and N utilization as compared to no irrigation treatment in 1987-88 only. Irrigation water helped in increased uptake of N in this season. W_2 treatment showed higher values in respect of all the three parameters, which was, however, not statistically different from W_1 in 1988-89. The sources of water and irrigation regimes interaction was significant in respect of total and fertilizer N uptake, Ndff and N utilization. The values were higher in plots receiving two irrigations with tube-well water. During 1988-89, uptake of total and fertilizer N, Ndff and N utilization by lentil were not influenced by irrigation. Total N uptake was considerably higher in 1988-89 which ranged from 33.8 to 39.4 kg ha^{-1} as compared with 4.4 - 12.9 kg ha^{-1} in 1987-88 in different treatments. The reason is attributable to biological nitrogen fixation by lentil due to use of *Rhizobium*

TABLE 3. TOTAL AND FERTILIZER N UPTAKE, NITROGEN DERIVED FROM FERTILIZER(NDFF) AND NITROGEN UTILIZATION BY LENTIL AS INFLUENCED BY SOURCES OF WATER AND IRRIGATION REGIMES.

Treatment	Total N, kg ha^{-1}			Fert. N, kg ha^{-1}			% Ndff			% N utilization		
	LW	TW	Mean	LW	TW	Mean	LW	TW	Mean	LW	TW	Mean
1987-88												
W_0	4.4	5.6	5.0c	0.41	0.55	0.48c	9.18	9.93	9.56b	1.35	1.84	1.60c
W_1	8.3	9.9	9.1b	0.78	0.92	0.85b	9.35	9.32	9.34b	2.59	3.06	2.83b
W_2	12.4	12.9	12.7a	1.25	194	1.59a	10.07	14.98	12.53a	4.15	6.46	5.31a
Mean	8.4a	9.5a	–	0.81a	1.14a	–	9.53a	11.41a	–	2.70a	3.79a	–
1988-89												
W_0	33.8	35.4	34.6a	0.62	0.48	0.55a	1.78	1.34	1.56a	3.10	2.38	2.74a
W_1	39.4	35.2	37.3a	0.78	0.54	0.66a	2.05	1.49	1.77a	3.92	2.71	3.32a
W_2	34.7	37.3	36.0a	0.54	0.86	0.70a	1.53	2.19	1.86a	2.72	4.31	3.52a
Mean	35.9a	36.0a	–	0.65a	0.63a	–	1.79a	1.67a	-	3.25a	3.14a	–

Figures followed by the same letter in a column or row of a parameter are not statistically different.

TABLE 4. SOIL NITROGEN A-VALUES* AND FOR THE REFERENCE CROP (WHEAT) AND LENTIL AND AMOUNT OF NITROGEN FIXED BY LENTIL AS INFLUENCED BY SOURCES OF WATER AND IRRIGATION REGIMES.

Treatment	Nitrogen A-values, kg ha^{-1}						Utilization of applied N by lentil %			Amount of N fixed by lentil** kg ha^{-1}		
	Reference crop			Lentil								
	LW	TW	Mean	LW	TW	Mean	LW	TW	Mean	LW	TW	Mean
1987-88												
W_0	268	220	244c	296	272	284a	1.35	1.84	1.84c	0.38	0.96	0.67b
W_1	239	205	222b	290	291	291a	2.59	3.06	2.83b	1.32	2.63	1.98a
W_2	177	166	172c	268	170	219b	4.15	6.46	5.31a	3.77	0.29	2.01a
Mean	228a	197a	–	285a	244a	–	2.70a	3.79a	–	1.82a	1.28a	–
1988-89												
W_0	309	424	366a	1122	1549	1335a	3.10	2.38	2.74a	23.6	24.8	24.2a
W_1	280	222	251b	969	1376	1172a	3.92	2.71	3.32a	27.6	28.7	28.2a
W_2	198	309	254b	1294	1000	1147a	2.72	4.31	3.52a	28.7	23.2	26.0a
Mean	262b	318a	–	1129b	1308a	–	3.25a	3.14a	–	26.6a	25.6a	–

Figures followed by the same letter in a column or row of a parameter are not statistically different.

inoculated seeds during 1988-89.

Nitrogen fixation by lentil. Table 4 shows the soil A-values for N for both the reference crop (wheat) and lentil and the amount of N fixed by lentil. Amount of N fixed by lentil was negligible in 1987-88 which ranged between 0.258 – 3.77 kg ha^{-1} in different treatments. The smaller amount of N fixation by lentil is due to the poor performance of the crop in the salt-affected soils. Nodulation of lentil was not observed during the crop growth in 1987-88. During 1988-89, the amount of N fixed by lentil increased significantly and ranged between 23.2 and 28.7 kg ha^{-1} in different treatments. There were, however, no significant difference among the sources of water and irrigation regimes. The increased amount of N fixation by lentil during this growth period is attributed to the use of *Rhizobium* inoculum. Nodulation in the crop was considerable even under this adverse soil saline conditions.

Higher amount of N fixed by nodule crops was reported by many workers [4-7]. But these were done under normal soil conditions. The findings of the present study indicated that growing of lentil in the salt-affected soils can be made successful with the use of *Rhizobium* inoculated seeds only. Under normal weather condition of winter season (November-March) lentil may not need any irrigation. Most of the nitrogen needs can be met from the atmospheric nitrogen fixed in the soil by the crop itself. Therefore, it may be possible to obtain a considerable yield of lentil in the salt-affected soils instead of keeping it fallow.

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References

1. Z. Karim, S.G. Hussain and M. Ahmed, Soil Publication No. 33, 63 (1990).
2. A.K.M. Habibullah, *A Reconnaissance* Survey, *Soil and Water Salinity,* (1986), Vol. III, pp. 66.
3. I.P. Abrol and R.K. Gupta, Proc. Int. Workshop on Evaluation for Sustainable Land Management, IBSRAM Proc. No. **12**(2), 253 (1991).
4. M. Fried and H. Broeshart, Plant and Soil, **62,** 331 (1981).
5. B.L. Vasilas and G.E. Ham, Agron. J., **76,** 759 (1976).
6. A.K. Podder, M.A. Sattar and M.L. Das, Progress Report IAEA Research Contract No. 4503/DP, Presented in RCM at Harbin, China, (1992), pp. 23.
7. M.A. Sattar, A.K. Podder and S.K.A. Danso, Bangladesh J. Sci. Res. (Special Issue), 73-85 (1990).
8. S.M. Rahman, S.U. Patwary and Sultana Ahmed, Bangladesh J. Nuclear Agric., **3,** 8 (1987).
9. IAEA, Tracer Manual on Crops and Soils, STI/DOC/10/171, IAEA, Vienna, (1976), pp. 277.
10. M. Fried and V. Middleboe, Plant and Soil, **47,** 713 (1977).
11. M. Fried and H. Broechart, Plant and Soil, **43,** 707 (1975).