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STUDIES ON ESP AND NITROGEN LEVELS AND THEIR INTERACTION EFFECT ON FORAGE SORGHUM YIELD, PROTEIN AND NUTRIENT UPTAKE

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SUMMARY

The present investigation was carried out in the Department of Soil Science, CCSHAU, Hisar during **kharif** season in screen house. The experiment was conducted on four ESP levels (control, 15, 30 and 45) soil and four N levels (0, 40, 80 and 120 kg/ha) indicated that overall dry matter yield of forage sorghum decreased with increasing ESP levels and increased with increasing N levels. The interaction effect of ESP levels and nitrogen levels on dry matter yield of forage sorghum was found significant. At highest level of ESP (45) the dry matter yield increased with the increasing nitrogen level in the tune of 12.30, 21.91 and 34.40 per cent as compared to N control at 40, 80 and 120 kg/ha, respectively. The plant height and protein content in sorghum decreased with increasing ESP levels and increased with increasing N levels. The overall uptake of N, P, K, Ca, Mg, Na and S by forage sorghum crop decreased with increasing ESP levels and increased with increasing N levels. A significant interactive effect of ESP and N levels on nutrient uptake by sorghum crop was observed. The overall uptake of micronutrients (Zn, Cu, Mn and Fe) by forage sorghum crop decreased with increasing ESP levels and increased with increasing N levels. A significant interaction effect of ESP and N levels on micronutrients uptake by sorghum crop was observed. The soil pH decreased at harvest of sorghum irrespective of ESP levels, whereas no clear trend was observed on the soil EC. The water soluble calcium increased slightly in post-harvest soil samples as compared to initial calcium status. Exchangeable Na content in the soil increased with the increasing ESP levels. The exchangeable Na content was higher in initial soil samples as compared to post-harvest soil samples.

Key words : ESP, nitrogen, nutrients uptake, dry matter yield, protein content, sorghum

Sorghum is an important fodder crop in India. It is an ideal forage crop due to its quick growth, high yielding ability, high dry matter content and leafiness. Moreover, it has a wider adaptability, drought tolerance and it can be grown under relatively medium to low soil fertility and moisture conditions in semi-arid areas. This crop provides nutritious fodder of good quality for fairly long periods of time. Because of the ever increasing demand for food grains to meet the requirements of teaming population, there is very little, rather no scope to increase the area under fodder crops. Furthermore, as it is difficult to devote more acreage under fodder crops, we are left with only one alternative to increase the fodder productivity in the country by increasing the areas by growing fodder crops on salt affected soils. Among salt affected soils, sodic soils have prominent place. Excess exchangeable sodium and high pH characteristics of sodic soils are responsible for deterioration in soil physico-chemical characteristics resulting in poor air and water movement in the soil which ultimately adversely affects growth, yield, chemical composition and nutrient uptake by the plants (Singh *et al.*, 2014a).

The yield and quality of fodder sorghum are greatly influenced by the soil condition, type and amount of salts present and the agronomic practices including application of fertilizer and irrigation. Generally sodic soils are found deficient in nitrogen. Hence, the requirement of nitrogen for growing crops in these soils is relatively more. Urea fertilizer is a major of nitrogen and used in the country, which supplies more than 80 per cent of the total nitrogen demand. The consumption of urea as a source of nitrogen will increase in future due to its low cost among the solid nitrogenous fertilizers. When urea is applied into the soil, it is rapidly hydrolyzed by extracellular enzyme 'urease' into ammonium carbonate, which is unstable in soil and readily decomposes into ammonia, carbon dioxide and water. The formation of ammonia as a result of urea hydrolysis initially increases soil pH. The ammonia formed is either taken up by the plants, fixed, lost through volatilization or nitrified to nitrite and later to nitrates. Hence, the requirement of nitrogen for growing sorghum in these soils is relatively high. The information on effect of sodicity at different nitrogen levels on fodder sorghum is meagre. Therefore, keeping the above points in view, present investigation was undertaken.

MATERIALS AND METHODS

The present study was carried out in the Department of Soil Science, CCS Haryana Agricultural University, Hisar during **kharif** season in screen house in the pots. The experiments were conducted on sandy loam soil which is having initial pH (1:2) 8.21 and ESP 7.88. Soil of different ESP (15, 30 and 45) was prepared through adopting the standard procedure given by Bains and Fireman (1979). Observed ESP was 7.88, 13.86, 31.15 and 43.79, respectively. The experiment was conducted in screen house to study the effect of different ESP levels (control, 15, 30 and 45) on sorghum with fixed 80 kg N/ha dose and different nitrogen levels 0, 40, 80 and 120 kg N/ha on sorghum at an ESP of 45 and their interaction. Soil samples were collected from each pot after harvest of crop and analyzed for pH, EC, soluble calcium and magnesium and exchangeable sodium. Effect of different ESP levels was studied on sorghum (HC-308) in three replications in factorial CRD. For data recording, above ground plant was harvested at 50 per cent flowering. Analyses of plant and soil samples were carried out as per prescribed laboratory standard procedures. The data on dry matter yield (g/pot), plant height (cm), protein content (%), nutrient uptake (mg/pot) and micronutrient uptake (mg/pot) were recorded.

RESULTS AND DISCUSSION

Effect of ESP and Nitrogen Levels on Dry Matter Yield

Data in Table 1 and Fig. 1 reveal that dry matter yield of sorghum decreased significantly with increasing ESP levels, irrespective of N levels. The overall decrease in dry matter of sorghum with increasing ESP was 10.94, 42.62 and 58.43 per cent at 15, 30 and 45 ESP, over control, irrespective of N levels. A perusal of data indicated that dry matter yield of sorghum increased significantly with all levels of N application (40, 80 and 120 kg/ha) to the tune of 28.15, 45.50 and 56.38 per cent, over zero nitrogen, irrespective of ESP levels. The increase in dry matter yield with increasing nitrogen levels was reported by various workers (Kumar *et al*., 2012; Duhan, 2013; Mitesh Bhoya *et al.*, 2013; Rana *et al.*, 2013; Singh *et al.*, 2014a; Somashekar *et al.*, 2014, 2015). This showed that sorghum in sodic soils responded to higher doses of applied nitrogen owing to their poor organic matter and available nitrogen status. Increasing salt levels of the growth caused a marked inhibitory effect on fresh and dry weights and maximum reduction in biomass was observed at highest salt level (Uppadyay *et al*., 2012).

TABLE 1

Effect of ESP and nitrogen levels on dry matter yield (g/pot) of sorghum

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	34.64	28.78	18.42	15.93	24.44
40	43.52	38.17	25.70	17.89	31.32
80	48.90	45.15	28.78	19.42	35.56
120	52.84	48.13	30.35	21.57	38.22
Mean	44.98	40.06	25.81	18.70	

C. D. (P=0.05) : Nitrogen=1.44, ESP=1.44, Nitrogen x ESP=2.87

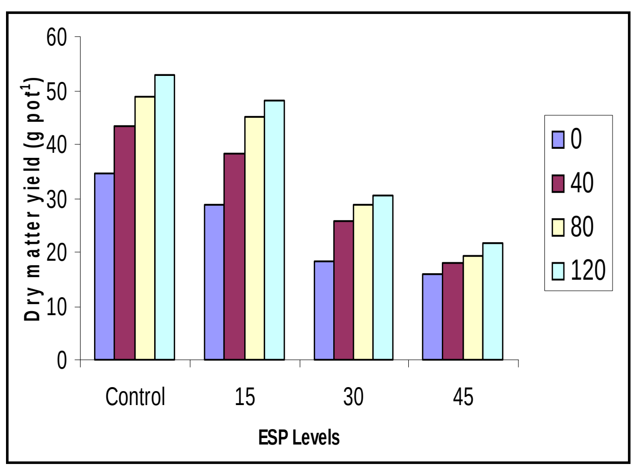

Fig. 1. Effect of ESP and nitrogen levels on dry matter yield (g/pot) of sorghum crop.

The growth suppression in sodic soils may be due to poor soil structure leading to the problem of aeration, low water availability and nutritional disorders. Structural deterioration of physical properties of soils, direct toxic effect, production of toxic substances within plants, etc. were put forth to explain the detrimental effects of exchangeable Na on plant growth. Similarly, Singh *et al.* (2014a) also reported the decrease in dry matter yield of sorghum with increasing ESP levels.

The interaction effect of ESP and nitrogen levels on dry matter yield of sorghum crop was found to be significant. Application of nitrogen increased dry matter yield to the extent of 25.63, 41.17 and 52.54 per cent at 40, 80 and 120 kg/ha, respectively, as compared to no nitrogen application or control. At 15 ESP, with addition of nitrogen, increased the dry matter yield to the extent of 32.63, 56.88 and 67.23 per cent, over N control, with the respective application of 40, 80 and 120 kg N/ha. The dry matter yield increased with increasing N levels, the increase was 64.77 per cent at 120 kg N/ha, as compared with no nitrogen application or control at 30 ESP. At an ESP of 45 also, dry matter yield increased with the increase in N application rate to the tune of 12.30, 21.91 and 34.40 per cent, as compared to N control, at 40, 80 and 120 kg N/ha, respectively. To compare the effect of ESP levels on individual N level, the data presented clearly showed the decreasing trend in dry matter yield of sorghum at each nitrigen level, with increasing ESP levels. At N control, the decreasing trend was observed to the tune of 16.92, 46.82 and 46.82 per cent, at 15, 30 and 45 ESP, respectively, as compared to control. At 40 kg N/ha, the decrease was to the extent of 12.29, 40.95 and 58.89 per cent, respectively, at 15, 30 and 45 ESP, as compared to control. While in case of 80 kg N/ha, the decrease was 7.67, 41.15 and 60.29 per cent, at 15, 30 and 45 ESP, respectively, as compared to control. As compared with the control at 15, 30 and 45 ESP, the decrease was 8.91, 42.56 and 59.18 per cent, respectively, at 120 kg N/ha.

Fig. 1 shows that the maximum increase in dry matter yield was observed at initial N dose (40 kg N/ha) and thereafter a decreasing trend in dry matter yield was obtained up to 120 kg N/ha. From these results, it was concluded that the response of nitrogen was found greater at initial dose and then its response got diminished at later application. A perusal of the data clearly showed the less response of N application at 45 ESP as compared to low ESP levels. Singh *et al.* (2014 a, b) also obtained the similar results of decreasing magnitude of response to N application, with increasing ESP levels on pearl millet and sorghum.

Effect of ESP and Nitrogen Levels on Plant Height of Sorghum Crop

Data presented in Table 2 reveal that plant height in sorghum decreased significantly with increasing ESP levels, irrespective of N levels. The mean decrease in plant height was 3.75, 10.71 and 19.40 per cent at 15, 30 and 45 ESP levels, respectively, as compared to control. Data reveal that with the addition of nitrogen, at all ESP levels the height of sorghum plant increased. The extent of increase was observed 4.42, 8.43 and 10.51 per cent, over no nitrogen, with the respective application of 40, 80 and 120 kg N/ha. In a field experiment on black clay soils at Dharwad revealed that the increasing nitrogen levels from 80 to 120 kg/ha produced significantly higher growth and yield in pearl millet (Hegde *et al.*, 2004). The adverse effect of ESP on plant height was mediated through its effect on nutritional disorders related to high soil pH, deteriorated soil physical properties and direct effect of excess sodium, or a combination of these factors. The detrimental effects of increased ESP levels in sodic soil on plant growth could be attributed to presence of high Na content in soil in available form. The interaction effect of ESP and nitrogen levels on plant height of sorghum crop was found to be non-significant.

TABLE 2

Effect of ESP and nitrogen levels on plant height (cm) of sorghum

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	137.13	131.09	121.18	108.72	124.53
40	142.82	136.31	126.16	114.82	130.03
80	146.89	142.12	132.31	118.81	135.03
120	149.11	144.84	134.63	121.88	137.62
Mean	143.99	138.59	128.57	116.06	

C. D. (P=0.05) : Nitrogen=1.68, ESP=1.68, Nitrogen x ESP=NS

Effect of ESP and Nitrogen Levels on Crude Protein Content

Increasing levels of ESP from control to 45 decreased the crude protein content, regardless of N levels (Table 3). The mean decrease in mean crude protein content in sorghum crop was 3.01, 7.41 and 13.19 per cent at 15, 30 and 45 ESP, respectively, as compared to control. Irrespective of ESP levels, with the addition of nitrogen, the crude protein content in sorghum increased. The extent of increase was observed 6.51, 11.29 and 14.08 per cent, over N control, with the respective application of 40, 80 and 120 kg N/ha. The interaction effect of ESP and nitrogen levels on crude protein content in sorghum crop was found to be non-significant. Increased crude protein content in sorghum in normal soil, with increasing nitrogen levels is in accordance with the findings of Mayub *et al.* (2002). The decrease in crude protein content with increasing ESP was due to decrease in nitrogen content with the increasing soil ESP which may be attributed to reduced losses of soil nitrogen through ammonia volatilization (Singh *et al.*, 2015) and deteriorating soil physico-chemical characteristics resulting in poor root development. Similar results were also obtained by Rana *et al.* (2013), Somashekar *et al.* (2014) and Singh *et al.* (2014 a, b). The application of higher doses of nitrogen levels on pearl millet genotypes produced significantly higher crude protein yield in green forage pearl millet (Damame *et al*., 2013). The increase in protein of pearl millet was reported by various workers (Kumar *et al*., 2012).

TABLE 3
Effect of ESP and nitrogen levels on crude protein content (%) of sorghum

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	7.94	7.75	7.44	7.00	7.53
40	8.50	8.25	7.88	7.44	8.02
80	8.94	8.63	8.25	7.69	8.38
120	9.19	8.88	8.44	7.88	8.59
Mean	8.64	8.38	8.00	7.50	

C. D. (P=0.05) : Nitrogen=0.10, ESP=0.10, Nitrogen x ESP=NS

Effect of ESP and Nitrogen Levels on Uptake of Nutrients

Nitrogen uptake : The uptake of nitrogen (Table 4) decreased significantly at all ESP levels, over control, irrespective of nitrogen application rates. The extent of decrease observed was 13.58, 46.86 and 64.03 per cent at 15, 30 and 45 ESP, respectively, as compared to control. Nitrogen uptake increased significantly at all the levels of N application, over control, irrespective of ESP levels. The extent of increase in N uptake was 36.67, 62.52 and 79.31 per cent, over N control, with the respective application of 40, 80 and 120 kg N/ha. Similar trend of nitrogen uptake was observed in pearl millet (Singh *et al.*, 2014b) and in maize (Singh *et al.*, 2015).

TABLE 4
Uptake of nitrogen (mg/pot) by sorghum plant at different ESP and nitrogen levels

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	439.93	356.87	219.20	178.42	298.60
40	591.87	503.84	323.82	212.89	408.11
80	699.27	623.07	379.90	238.87	485.28
120	776.75	683.45	409.73	271.78	535.43
Mean	626.95	541.81	333.16	225.49	

C. D. (P=0.05) : Nitrogen=19.40, ESP=19.40, Nitrogen x ESP=38.80

The interaction effect of ESP and nitrogen levels on nitrogen uptake by sorghum plant was found significant. With increasing N levels from 0 to 120 kg/ha, N uptake increased from 439.93 to 776.75, 356.87 to 683.456, 219.20 to 409.73 and 178.42 to 271.78 mg/pot at control, 15, 30 and 45 ESP, respectively. The highest N uptake was recorded at 120 kg N/ha followed by 80, 40 and 0 kg N/ha treatment levels. The decreased N uptake with increasing ESP level resulted in decreased dry matter of sorghum. Decreased nitrogen uptake with increasing ESP is in agreement with the findings of Singh *et al.* (2014b) in pearl millet and Sharma *et al.* (2001) in pigeonpea.

Phosphorus uptake : Data presented in Table 5 reveal that with the addition of nitrogen at all ESP levels increased the P uptake. The extent of increase was 46.81, 83.66 and 111.28 per cent, over N control, with the respective application of 40, 80 and 120 kg N/

TABLE 5
Effect of ESP and nitrogen levels on uptake of phosphorus (mg/pot) by sorghum

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	69.28	51.80	27.63	20.71	42.36
40	100.10	76.34	43.69	28.62	62.19
80	122.25	99.33	54.68	34.96	77.80
120	137.38	110.70	66.77	43.14	89.50
Mean	107.25	84.54	48.19	31.86	

C. D. (P=0.05) : Nitrogen=7.12, ESP=7.12, Nitrogen x ESP=14.23

ha. A perusal of the data given reveals that a significant decrease in P uptake to the extent of 21.17, 55.07 and 70.29 per cent was observed at 15, 30 and 45 ESP, as compared to control soil, irrespective of N levels. With increasing ESP levels, decreased P uptake was also confirmed by Singh *et al.* (2014b) in pearl millet and Singh *et al.* (2015) in maize.

The interaction effect of ESP and nitrogen on the uptake of phosphorus by sorghum was found significant. Increasing N levels from 0 to 120 kg/ha, increased N uptake from 69.28 to 137.38 mg/pot in control soil, from 51.80 to 110.70 mg/pot at 15 ESP, from 27.63 to 66.77 mg/pot at 30 ESP and from 20.71 to 43.14 mg/pot at 45 ESP. At zero nitrogen, the P uptake decreased from 69.28 to 20.71 mg/pot, whereas at 120 kg/ha it decreased from 137.38 to 43.14 mg/pot, as the ESP increased from control to 45. Singh *et al.* (2014b) also reported an increase in P uptake with increasing nitrogen doses in pearl millet, irrespective of ESP levels.

Potassium uptake : A significant decrease in potassium uptake at all the levels of ESP (15, 30 and 45) was 13.15, 45.80 and 65.14 per cent, respectively, as compared to control soil, irrespective of N levels (Table 6). With increasing ESP levels, decreased K uptake was also noted by Singh *et al.* (2014a) in sorghum and Balak Ram and Misra (2004) in German chamomile. Data reveal that potassium uptake in sorghum increased significantly in the extent of 32.65, 54.60 and 69.40 per cent, over no nitrogen level, at the respective corresponding levels of N (40, 80 and 120 kg N/ha), irrespective of ESP level. The interactive effect of ESP and nitrogen levels on K uptake by sorghum was found significant. At all ESP levels, with increasing nitrogen levels, the magnitude of increase was found maximum at initial N application rate (40 kg/ha), as compared to higher N application rate. Also, the magnitude of response to N application was found minimum at 45 ESP, as compared with lower ESP. The increasing level of ESP, on the other hand, resulted in progressive decline in the uptake of K by sorghum crop, at each level of N application. These results are in agreement with the findings of Singh *et al.* (2014b, 2015) in pearl millet and maize, in which, K uptake increased with increasing nitrogen doses, irrespective of ESP levels.

TABLE 6

Uptake of potassium (mg/pot) by sorghum at different ESP and nitrogen levels

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	595.81	486.38	296.56	226.21	401.24
40	774.66	660.34	429.19	264.77	532.24
80	889.98	799.16	495.02	297.13	620.32
120	977.54	866.34	534.16	340.81	679.71
Mean	809.50	703.05	438.73	282.23	

C. D. (P=0.05) : Nitrogen=25.85, ESP=25.85, Nitrogen x ESP=51.70

Calcium uptake : Data in Table 7 reveal that uptake of calcium by sorghum decreased significantly at 15, 30 and 45 ESP, over control, irrespective of N levels. The decrease in calcium uptake with increasing ESP is in accordance with the findings of Singh *et al.* (2014a) in sorghum. The uptake of Ca by sorghum increased significantly, over N control, to the extent of 45.39, 77.87 and 104.66 per cent with the respective application of 40, 80 and 120 kg N/ha.

TABLE 7

Effect of ESP and nitrogen levels on uptake (mg/pot) of calcium by sorghum crop

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	145.49	115.12	66.31	46.20	93.28
40	208.90	171.77	102.80	59.04	135.62
80	249.39	216.72	123.75	73.80	165.92
120	285.34	250.28	139.61	88.44	190.91
Mean	222.28	188.47	108.12	66.87	

C. D. (P=0.05) : Nitrogen=6.42, ESP=6.42, Nitrogen x ESP=12.84

The interaction effect of ESP and nitrogen levels on calcium uptake by sorghum was found significant. At 120 kg N/ha, the increase in Ca uptake was to the extent of 96.12, 117.41, 110.54 and 91.43 per cent, at control, 15, 30 and 45 ESP, respectively, as compared to no nitrogen. The increasing level of ESP, on the other hand, resulted in progressive decline in the uptake of Ca by sorghum crop, at each level of N application. At an ESP of 45 the decrease in Ca uptake by sorghum crop was 68.25, 71.74, 70.41 and 69.01 per cent at 0, 40, 80 and 120 kg N/ha, respectively, compared with the control soil. The magnitude of response to N application, however, decreased with the increasing ESP levels.

Magnesium uptake : Table 8 shows that irrespective of N levels, uptake of magnesium by sorghum decreased significantly to the level of 22.07, 57.47 and 75.27 per cent with the successive respective ESP levels of 15, 30 and 45, as compared to control. Application of various levels of nitrogen viz., 40, 80 and 120 kg/ha, irrespective of soil ESP, increased the respective Mg uptake by sorghum plant. The mean Mg uptake was observed 36.76, 60.20, 79.90 and 93.47 mg/pot at 0, 40, 80 and 120 kg N/ha. In pearl millet, similar results were reported by Singh *et al*. (2014 a,b).

TABLE 8
Uptake of magnesium (mg/pot) by sorghum at different nitrogen and ESP levels

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	65.82	43.17	22.10	15.93	36.76
40	100.10	76.34	41.12	23.26	60.20
80	127.14	103.85	57.56	31.07	79.90
120	147.95	120.33	66.77	38.83	93.47
Mean	110.25	85.92	46.89	27.27	

C. D. (P=0.05) : Nitrogen=6.44, ESP=6.44, Nitrogen x ESP=12.88

The interaction effect of ESP and nitrogen on uptake of magnesium by sorghum was found significant. With increasing N levels from 0 to 120 kg/ha, increased Mg uptake from 65.82 to 147.95, 43.17 to 120.33, 22.10 to 66.77 and 15.93 to 38.83 mg/pot at control, 15, 30 and 45 ESP, respectively. At zero nitrogen, the Mg uptake decreased from 65.82 to 15.93 mg/pot, whereas at 120 kg/ha it decreased from 147.95 to 38.83 mg/pot, as the ESP increased from control to 45.

Sodium uptake : A perusal of data in Table 9 shows that irrespective of nitrogen application rate, sodium uptake by sorghum was found maximum at 15 ESP and minimum at an ESP of 45. Application of nitrogen, irrespective of soil ESP, increased Na uptake significantly, at all the nitrogen levels (40, 80 and 120 kg/ha). The maximum Na uptake (85.18 mg/pot) was found at 15 ESP soil and minimum (61.32 mg/pot) at an ESP of 45. These findings are also in accordance with the findings of Balak Ram and Misra (2004) in German chamomile and Singh *et al.* (2015) in maize. In respective of nitrogen application rate, minimum Na uptake (33.03 mg/pot) was observed at control, whereas maximum (90.39 mg/pot) at 120 kg N/ha. The interaction effect of ESP and nitrogen levels on Na uptake by sorghum crop was found significant. Increasing N levels from 0 to 120 kg/ha increased Na uptake from 34.64 to 100.40 mg/pot at control, from 34.54 to 105.89 mg/pot at ESP 15, from 29.47 to 81.95 mg/pot at 30 ESP and from 33.45 to 73.34 mg/pot at 45 ESP.

TABLE 9
Uptake of sodium (mg/pot) by sorghum as affected by different ESP and nitrogen levels

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	34.64	34.54	29.47	33.45	33.03
40	56.58	57.26	51.40	46.51	52.94
80	78.24	85.79	66.19	58.26	72.12
120	100.40	105.89	81.95	73.34	90.39
Mean	67.46	70.87	57.25	52.89	

C. D. (P=0.05) : Nitrogen=6.16, ESP=6.1, Nitrogen x ESP=12.32

Sulphur uptake : A significant decrease in sulphur uptake, irrespective of N levels, at all the levels of ESP (15, 30 and 45) to the extent of 19.90, 54.26 and 74.19 per cent was observed, over control (Table 10). Application of nitrogen, irrespective of soil ESP, increased S uptake significantly, at all the respective N levels. Minimum S uptake (46.06 mg/pot) was observed at no nitrogen, whereas maximum (113.34 mg/pot) at 120 kg N/ha. Similar findings were also reported by Singh *et al*. (2014 a, b) in pearl millet.

TABLE 10
Effect of ESP and nitrogen levels on uptake (mg/pot) of sulphur by sorghum crop

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	79.67	57.56	29.47	17.52	46.06
40	113.15	87.79	51.40	28.62	70.24
80	146.70	121.91	69.07	36.90	93.64
120	174.37	144.39	84.98	49.61	113.34
Mean	128.47	102.91	58.73	33.16	

C. D. (P=0.05) : Nitrogen=6.05, ESP=6.05, Nitrogen x ESP=12.10

The interactive effect of ESP and nitrogen levels on S uptake by sorghum was found significant. At all ESP levels, with increasing N levels, the magnitude of increase was found maximum at initial N application rate (40 kg/ha), as compared to higher N application rate. The increasing level of ESP, on the other hand, resulted in progressive decline in the uptake of S by sorghum crop, at each level of N application.

Effect of ESP and Nitrogen Levels on Uptake of Micronutrients

Zinc uptake : Data in Table 11 reveal that uptake of zinc by sorghum decreased significantly with increasing levels of ESP. The overall uptake of zinc by sorghum decreased by 17.19, 52.34 and 71.10 per cent at 15, 30 and 45 ESP levels, as compared to non-sodic control soil. The uptake of Zn by sorghum crop increased significantly with increasing levels of nitrogen. The overall increase in zinc uptake by sorghum was 52.0, 90.0 and 120.0 per cent with the application of 40, 80 and 120 kg N/ha, as compared to N control.

TABLE 11
Effect of ESP and nitrogen levels on uptake (mg/pot) of zinc by sorghum crop

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	0.81	0.62	0.33	0.24	0.50
40	1.19	0.96	0.56	0.33	0.76
80	1.45	1.24	0.71	0.40	0.95
120	1.65	1.42	0.82	0.51	1.10
Mean	1.28	1.06	0.61	0.37	

C. D. (P=0.05) : Nitrogen=0.06, ESP=0.06, Nitrogen x ESP=0.12

The interaction effect of ESP and nitrogen levels on Zn uptake by sorghum crop was found significant. At 120 kg N/ha, the increase in Zn uptake was to the extent of 103.70, 129.03, 148.48 and 112.50 per cent, at control, 15, 30 and 45 ESP, respectively, as compared to zero nitrogen. The increasing level of ESP, on the other hand, resulted in progressive decline in the uptake of Zn by sorghum, at each level of N application. At an ESP, of 45 the decrease in Zn uptake by sorghum crop was 70.35, 72.27, 72.41 and 69.09 per cent at 0, 40, 80 and 120 kg N/ha, respectively, compared with the control soil. Similar trend of zinc uptake was also reported by Singh *et al.* (2014 a, b; 2015) in sorghum, pearl millet and maize.

Copper uptake : A perusal of the data given in Table 12 reveals that copper uptake by sorghum increased significantly to the extent of 44.44, 77.78 and 100.0 per cent, over control, at the respective dose of 40, 80 and 120 kg N/ha, irrespective of ESP levels. A significant decrease in copper uptake, irrespective of N levels, at all the levels of ESP (15, 30 and 45) to the extent of 13.64, 54.55 and 72.73 per cent was observed, over control. Above results were supported by Singh *et al.* (2014 a, b; 2015).

TABLE 12
Effect of ESP and nitrogen levels on uptake (mg/pot) of copper by sorghum crop

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	0.15	0.12	0.06	0.04	0.09
40	0.20	0.17	0.09	0.06	0.13
80	0.24	0.22	0.12	0.07	0.16
120	0.28	0.24	0.13	0.08	0.18
Mean	0.22	0.19	0.10	0.06	

C. D. (P=0.05) : Nitrogen=0.01, ESP=0.01, Nitrogen x ESP=0.02

The interactive effect of ESP and nitrogen levels on Cu uptake by sorghum was found significant. At all ESP levels, with increasing N levels, the magnitude of increase was found maximum at initial N application rate (40 kg/ha), as compared to higher N application rate. The increasing level of ESP, on the other hand, resulted in progressive decline in the uptake of Cu by sorghum, at each level of N application.

Manganese uptake : Data in Table 13 show that irrespective of nitrogen levels, uptake of manganese by sorghum decreased significantly to the extent of 16.0, 54.0 and 72.0 per cent with the successive respective levels of 15, 30 and 45 ESP. Addition of various levels of N viz., 40, 80 and 120 kg/ha, irrespective of soil ESP, increased the respective Mn uptake by sorghum. The per cent increase in manganese uptake in sorghum was 60, 108 and 148 per cent at 40, 80 and 120 kg N/ha, as compared with zero nitrogen. More or less similar findings were reported by Singh *et al.* (2014 a, b; 2015).

TABLE 13
Effect of ESP and nitrogen levels on uptake (mg/pot) of manganese by sorghum crop

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	0.74	0.54	0.29	0.22	0.45
40	1.13	0.93	0.50	0.31	0.72
80	1.42	1.27	0.68	0.39	0.94
120	1.72	1.46	0.79	0.49	1.12
Mean	1.25	1.05	0.57	0.35	

C. D. (P=0.05) : Nitrogen=0.04, ESP=0.04, Nitrogen x ESP=0.08

The interactive effect of ESP and nitrogen levels on manganese uptake by sorghum was found significant. At all ESP levels, with increasing N levels, the magnitude of increase was found maximum at initial N application rate (40 kg/ha), as compared to higher application rate. The increasing level of ESP, on the other hand, resulted in progressive decline in the uptake of Mn by sorghum crop, at each level of N application. The magnitude of response to nitrogen application, however, decreased with the increasing ESP levels.

Iron uptake : Data presented in Table 14 reveal that the application of nitrogen, at all ESP levels increased the Fe uptake. The extent of increase was 30.79, 51.48 and 64.70 per cent, over zero nitrogen, with the application of 40, 80 and 120 kg N/ha, respectively. A significant decrease in Fe uptake was to the extent of 12.42, 45.22 and 62.34 per cent was observed at 15, 30 and 45 ESP, over control.

TABLE 14
Effect of ESP and nitrogen levels on uptake (mg/pot) of iron by sorghum crop

Nitrogen levels (kg/ha)	ESP levels				Mean
	Control	15	30	45	
0	9.42	7.68	4.75	3.87	6.43
40	12.02	10.36	6.77	4.48	8.41
80	13.75	12.50	7.74	4.99	9.74
120	15.04	13.47	8.26	5.60	10.59
Mean	12.56	11.00	6.88	4.73	

C. D. (P=0.05) : Nitrogen=0.37, ESP=0.37, Nitrogen x ESP=0.75

The interaction effect of ESP and nitrogen levels on Fe uptake by sorghum crop was found significant. At 120 kg N/ha, the increase in Fe uptake was to the extent of 59.66, 75.39, 73.89 and 44.70 per cent, at control, 15, 30 and 45 ESP, respectively, as compared to zero nitrogen. The increasing level of ESP, on the other hand, resulted in progressive decline in the uptake of Fe by sorghum crop, at each level of N application. The magnitude of response to N application, however, decreased with the increasing ESP levels.

Uppadyay *et al*. (2012) while experimenting on *Ammi majus* reported that the accumulation of Zn and Cu in test plant decreased on increasing ESP levels. In maize and beans, the salt treatments lowered the uptake of micro-elements (Kudo *et al*., 2010). In pearl millet, the salt treatments also lowered the uptake of micro-elements (Singh *et al*., 2014b).

CONCLUSIONS

The dry matter yield of sorghum decreased with increasing ESP levels (control, 15, 30 and 45). The maximum (48.18 g/pot) and minimum (19.78 g/pot) dry matter yield of sorghum was recoded at control and 45 ESP, respectively. The plant height and protein content also decreased with increasing ESP levels. The uptake of N, P, K, Ca, Mg and S decreased with increasing ESP levels. The reduction in N uptake over control was 10.83, 46.77 and 65.22 per cent at 15, 30 and 45 ESP levels, respectively. The Na uptake by sorghum increased significantly up to an ESP of 15, as compared to control, whereas further increase in ESP at 30 and 45, it decreased significantly, over 15 ESP. The uptake of micronutrients (Zn, Cu, Mn and Fe) decreased with increasing ESP levels.

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