International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 13, 2018, pp.-6606-6609.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

EFFECT OF SOIL SODICITY AND IRON LEVELS ON SOIL PROPERTIES, YIELD ATTRIBUTES AND YIELD OF COWPEA

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Received: June 28, 2018; Revised: July 05, 2018; Accepted: July 06, 2018; Published: July 15, 2018

Abstract: A pot experiment was conducted during *kharif* season of 2016 at S.K.N. College of Agriculture, Jobner to study response of cowpea [*Vigna unguiculata* L Wilezek] to iron fertilization under different sodicity levels. Each four levels of sodicity (SAR 10, 15, 20, 25), and iron (0, 5, 10 and 15 kg/ha) were tested in completely randomized design with three replications. The results revealed that significantly higher ECe and DTPA-Fe content and lower pH and SAR in soil recorded under soil sodicity level of SAR 10 as compared to other levels. Growth attributes such as plant height, total nodules/plant, effective nodules/plant, nodule index and total chlorophyll content and yield attributes such as pods/plant, grains/pod and seed index, grain and stover yields were recorded significantly higher under soil sodicity level of SAR 10 compared to other higher levels of SAR. The significantly increased pH, SAR and decreased ECe, DTPA-Fe with increasing levels of sodicity. The growth and yield attributes and yields of cowpea significantly increased with increasing levels of Fe application.

Keywords: Cowpea, Iron, SAR, pH, EC, Chlorophyll, Nodule index

Citation: Kiran DoodhwaL, *et al.*, (2018) Effect of Soil Sodicity and Iron Levels on Soil Properties, Yield Attributes and Yield of Cowpea. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 13, pp.- 6606-6609.

Introduction

Cowpea [*Vigna unguiculata* L *Wilczek*] commonly known as lobia in India. It is one of the important *kharif* pulse crops grown for vegetable, grain, forage and green manuring across the country. This crop has great importance because of short duration, high yielding and quick growing in a wide variety of soil properties. Green tender pods are used as vegetable; contain moisture, protein carbohydrate and fat are 84.6%, 4.3%, 8.0% and 0.2%, respectively. In India, pulses were grown over 25.22 m ha area with an annual production of 19.25 million tonnes and an average productivity of 764 kg/ha [1]. In Rajasthan, the area under pulses is 42.02 lakh ha with the annual production 24.75 lakh metric tonnes and an average productivity of 589 kg/ ha, whereas, cowpea covers an area of 0.61 lakh ha with a production of 0.33 lakh tonnes and productivity of 555 kg/ha [2]. The per capita availability of pulses in India is 35.5 g/day as against the minimum requirement of 70 g/day/capita. In many parts of arid and semi-arid regions, groundwater which is often of poor quality is used as major source of irrigation. The continuous use of such water for irrigation creates salinity or sodicity in soil. The problem is aggravated in the areas where saline/sodic ground water is used as a main source of irrigation in good quality water scare areas. Salt affected soils cover an area of nearly 13.8 M ha in the country [3], and 1.24 M ha in Rajasthan and occurs to a greater or lesser extent in practically all the district of state [4]. SAR is a widely accepted index for characterizing of soil sodicity, which describes the proportion of sodium to calcium and magnesium in soil solution. As exchangeable sodium percentage (ESP) is used to characterize the sodicity of soils only, whereas, SAR is applicable to both soil and soil solution or irrigation water [5]. Iron being an essential micronutrient takes active part in the metabolic activities of the plant. It acts as activator of dehydrogenase, proteolase and peptidases enzymes, directly or indirectly involved in the synthesis of carbohydrates and proteins. Iron in chloroplast reflects the presence of cytochromes for performing various photosynthetic reduction processes.

The ferredoxins are Fe-S protein and are the first stable redox compound of the photosynthetic electron transport chain [6, 7] also showed that Fe deficiency due to high pH caused tissue necrosis and necrotic patches of leaf lamina of *Vigna mungo* and *Vigna radiata*. Increasing the sodicity and salinity reduce the plant nutrient dynamics and may adversely affect the crop. In this regards, less research work was done on graded level of salinity with respect to iron availability. The hypothesis was comprised with different levels of sodicity and its effect on the soil properties, yield attributes and yield of cowpea cultivated under graded doses of Fe.

materials and methods

A pot experiment was conducted at green house of Department of Plant Physiology, College of Agriculture, Jobner during 2016 in completely randomized design (CRD) with three replications. The experiment were consisted of each four levels of soil SAR (10, 15, 20, 25) and iron (control, 5, 10, 15 kg Fe/ha) and thereby, making 48 treatment combinations. The soil was loamy sand in texture, alkaline in reaction (pH 8.40), low in organic carbon (1.85 g/kg), available nitrogen (128 kg/ha), medium in available phosphorus (16 kg P_2O_5/ha), potassium (146 kg K_2O/ha) content and DTPA-Fe (4.8 mg/kg). Experimental soil having bulk density, particle density, Na, Ca, Mg, CO_3-, HCO_3, SO_4- , Cl-, CEC, exchangeable Na and ESP were 1.50 Mg/m3, 2.60 Mg/m3, 11 me/L, 1.2 me/L, 1.2 me/L, 1 me/L 3.55me/L, 2.65me/L, 6.15 me/L, 6 cmol (P+) kg/soil, 0.65 cmol/kg and 9.55, respectively. To attain the SAR level of 15, 20 and 25, salts were added in soil like NaCl, Na_2SO_4, $NaHCO_3$, Na_2CO_3, $CaCl_2$ and $MgCl_2$ in suitable proportion as per detailed given in [Table-1]. Iron was applied as per treatment in soil as basal dose through $FeSO_4.7H_2O$ calculated as 12.5, 25.0 and 37.5 mg/kg soil $FeSO_4.7H_2O$ for 5, 10 and 15 kg Fe/ha, respectively. Soil was filled with cylindrical ceramic pots (20 cm diameter and 28 cm height). Each pot contained 10 kg of soil.

Table-1 Ionic composition of soil

SAR	mmol/l							EC dS/m
	Na^{+}	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	
S_{10} (Control)	11.0	1.2	1.2	1.00	3.55	6.15	2.65	1.31
S_{15}	31.0	4.5	4.5	1.00	5.00	30.00	4.00	4.00
S_{20}	34.0	3.0	3.0	1.00	5.00	30.00	4.00	4.00
S_{25}	36.0	2.0	2.0	1.00	5.00	30.00	4.00	4.00

Table-2 Effect of soil sodicity and iron levels on pH, ECe, SAR, Organic Carbon, and DTPA-Fe in soil at harvest

Treatments	pH	EC (dS/m)	SAR	Organic carbon (%)	DTPA-Fe (ppm)
Soil sodicity (SAR)					
S_{10}	7.50	3.44	12.18	0.228	4.69
S_{15}	8.07	3.09	17.34	0.226	4.32
S_{20}	8.59	2.80	25.50	0.225	4.02
S_{25}	9.10	2.56	34.44	0.224	3.38
SEm$\pm$	0.15	0.07	0.56	0.005	0.10
CD (p= 0.05)	0.43	0.20	1.62	NS	0.28
Iron levels					
Fe_0 (control)	9.02	2.56	25.56	0.223	3.22
Fe_5 (5 kg Fe/ha)	8.59	2.87	23.40	0.225	3.96
Fe_{10} (10 kg Fe/ha)	8.03	3.09	21.32	0.227	4.43
Fe_{15} (15 kg Fe/ha)	7.63	3.37	19.18	0.228	4.81
SEm$\pm$	0.15	0.07	0.56	0.005	0.10
CD (p= 0.05)	0.43	0.20	1.62	NS	0.28

Table-3 Effect of soil sodicity and iron levels on total number of nodules, number of effective nodules and nodule index total chlorophyll content in leaves at 45 days.

Treatments	Plant height (cm)	Total nodules/plant	Effective nodules/plant	Nodule index	Total chlorophyll content (mg/g)
Soil sodicity (SAR)					
S_{10}	67.65	26.18	22.31	2.89	3.86
S_{15}	63.63	22.45	17.79	2.66	3.58
S_{20}	59.18	19.74	16.00	2.32	3.28
S_{25}	54.90	18.07	13.95	2.11	3.01
SEm$\pm$	1.42	0.51	0.43	0.06	0.08
CD (p= 0.05)	4.11	1.48	1.23	0.17	0.23
Iron levels					
Fe_0 (control)	54.28	18.11	14.68	2.18	3.05
Fe_5 (5 kg Fe/ha)	58.62	20.13	16.48	2.36	3.29
Fe_{10} (10 kg Fe/ha)	63.78	22.09	18.74	2.55	3.55
Fe_{15} (15 kg Fe/ha)	68.68	26.11	20.15	2.89	3.84
SEm$\pm$	1.42	0.51	0.43	0.06	0.08
CD (p= 0.05)	4.11	1.48	1.23	0.17	0.23

Table-4 Effect of soil sodicity and iron levels on yield attributes

Treatments	Pods/plant	Grains/pod	Seed index (g)	Grain yield (g/pot)	Straw yield (g/pot)
Soil sodicity (SAR)					
S_{10}	6.64	6.35	6.90	8.53	16.40
S_{15}	5.94	5.83	6.34	6.95	13.96
S_{20}	5.18	5.03	5.84	5.53	10.84
S_{25}	4.63	4.52	5.36	4.18	8.36
SEm$\pm$	0.13	0.13	0.14	0.16	0.32
CD (p= 0.05)	0.38	0.37	0.41	0.46	0.92
Iron levels					
Fe_0 (control)	4.50	4.56	5.21	4.19	8.39
Fe_5 (5 kg Fe/ha)	5.14	5.11	5.76	5.76	10.83
Fe_{10} (10 kg Fe/ha)	5.83	5.62	6.48	6.48	13.81
Fe_{15} (15 kg Fe/ha)	6.92	6.44	6.99	8.76	16.53
SEm$\pm$	0.13	0.13	0.14	0.16	0.32
CD (p= 0.05)	0.38	0.37	0.41	0.46	0.92

Table-5 Interactive effect of soil sodicity and iron levels on grain and stover yield (g/pot)

Treatments	Fe_0		Fe_5		Fe_{10}		Fe_{15}	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
S_{10}	5.68	11.11	7.80	14.34	8.78	18.28	11.87	21.88
S_{15}	4.62	9.45	6.36	12.20	7.15	15.56	9.67	18.62
S_{20}	3.68	7.34	5.06	9.48	5.69	12.08	7.69	14.46
S_{25}	2.78	5.66	3.82	7.31	4.30	9.32	5.81	11.15
SEm+	0.32	0.64	-	-	-	-	-	-
CD (p= 0.05)	0.93	1.83	-	-	-	-	-	-

At the time of filling pots, the broken pieces of stone were placed in the bottom hole to allow free drainage. The cowpea cv. 'RC-19' was shown on 12th July, 2016 with a seed rate of 5 seeds per pot. The crop was harvested on 25th September, 2016. Fully mature and developed pods from randomly selected five plants from each plot were plucked and numbers of seeds were counted. The average number of pods and seeds/plants was worked out.

After threshing and winnowing the weight of seeds in each pot was recorded in g/pot.

statistical analysis

The experiment was conducted in a Factorial Complete Randomized Design (CRD) with three replications. Statistical data analysis was done at the 5% (p=0.05) level of significance and compared using least significant difference among the treatments [8]. The statistical package WASP 2.0 was used for data analysis.

Results and discussions

Effect of soil sodicity

The ECe and DTPA extractable Fe of soil decreased significantly ($p<0.05$) with increasing levels of SAR in soil [Table-2]. The SAR levels S_{20} and S_{25} significantly decreased the ECe and DTPA-Fe over S_{10}. Application of S_{15}, S_{20} and S_{25} SAR levels decreased ECe 10.16, 18.6 and 25.58% and DTPA-Fe as compared to control (S_{10}), respectively. The pH and SAR of soil tended to increase significantly with increasing levels of soil sodicity. Due to the soil sodicity levels the increase in soil pH was 7.6, 14.5 and 21.3%; SAR was 7.1, 12.7 and 17.6% under S_{15}, S_{20} and S_{25} as compared to control, respectively. The low degree of observed salinity at higher SAR level is due to the precipitation of alkaline earth was also reported by Chauhan *et al*. (1988) [9]. The results are in close agreement with the findings of Yadav and Tomar (1982), Sharma and Mandal (1982) and Joshi and Dhir (1998)]. Naga (2013) [10-13] reported that irrigation with sodic water having increased values of RSC (0, 4, 8 and 12 mmol/L) significantly increased the pH, ESP, $CaCO_3$ in soil, while, it decreased significantly the ECe and available Fe in soil. The results are in close conformity with that of Netwal (2003), Pareek and Yadav (2011) and Kumari *et al*. (2015) [14-16]. The data on DTPA-Fe showed that there was a significant decrease in iron content with different level of SAR of soil. The native dominating $CaCO_3$ influenced the DTPA extractable Fe and it indicates that soils pH and oxidation reduction influenced the availability of iron. The results are in close agreement with the findings of Singh *et al*. (1999), Parkash *et al*. (1994), Chauhan (1992), and Patil and Malewar (1998),[17-20]. The correlation coefficient values again confirmed that DTPA-Fe content of soil negatively correlated with pH ($r = -0.971^{**}$) and SAR ($r = -0.809^{**}$) of soil.Soil sodicity levels were significantly influence the growth parameters of cowpea [Table-3]. Growth parameters of cowpea such as plant height, total chlorophyll content, total nodules/plant, effective nodules/plant and nodule index were significantly decreased with the increasing levels of SAR. The soil sodicity levels of S_{15}, S_{20}, and S_{25} were registered significantly lower plant height (6.0-18.8%), total chlorophyll content (7.3-22.0%), total nodules/plant (14.2-31.0%), effective nodules/plant (20.3-37.5%) and nodule index (8.0-27.0%) as compared to normal level of soil sodicity (S10). This might be due to inability of the crop to grow under high SAR is due to the toxicity of Na itself and Ca and K frequently becomes as limiting factor for plant growth [21]. The yield attributes and yields of cowpea significantly decreased with the increasing levels of soil sodicity [Table-4]. Number of pods/plant, grains/pod, seed index, seed and stover yields was decreased significantly with soil sodicity levels of S_{15}, S_{20} and S_{25} and were recorded the pods/plant (10.5-30.3%), grains/pod (8.2-28.8%), seed index (8.0-22.3%), seed (18.5-51.0%) and stover (14.9-49.0%) yields lower as compared to the normal soil S10. This is might be due to higher pH and SAR of soil and it responsible for the reduction in grain and straw yield by causing a restricted availability of water and nutrients to the plant. These findings are similar to the findings of Choudhary *et al*. (2011) [22] in wheat.

Effect of iron levels

The results revealed that ECe, pH, SAR, organic carbon and DTPA extractable Fe of soil as influenced by different levels of iron [Table-2]. The increasing levels of iron significantly decreased the pH and SAR of soil at the crop harvest and decreased the pH by 4.76, 10.97 and 15.41 %, and SAR by 8.45, 19.88 and 24.96% under Fe_5, Fe_{10} and Fe_{15} levels of iron, respectively as compared to control. The DTPA extractable Fe content of soil increased with the increasing levels of iron from Fe0 to Fe_{15}, significantly higher DTPA-Fe was maintained by Fe_{15} level as compared to its preceding levels and registered 18.69, 27.31 and 30.06% higher DTPA-Fe content in soil with application of Fe_5, Fe_{10} and Fe_{15} over control, respectively. Ghodsi *et al*. (2015) [23] reported that 20 mg/kg of iron oxide, significantly increased electrical conductivity of saturation extract (ECe), availability of nutrient elements P, Fe, and Cu in soil, while N, pH, SAR in soil decreased significantly. The soil application of different levels of iron significantly influences the growth parameters of cowpea (Table 3). The increasing levels of iron significantly increased the growth parameters such as plant height, total chlorophyll content, total nodules/plant, effective nodules/plant and nodule index and recorded higher 8.0, 17.5 and 26.5% of plant height, 7.9, 16.4 and 25.9% of total chlorophyll content, 11.2, 22.0 and 44.2% of total nodules, 12.3, 27.7 and 37.3% of effective nodules and 8.3, 17.0 and 32.6% of nodule index under Fe_5, Fe_{10} and Fe_{15} over control, respectively. Yield attributes and yields of cowpea significantly influenced by the soil application of iron levels [Table-4]. The increasing levels of iron significantly increased the pods/plant, grains/pod, seed index, seed and stover yields as compared to control and registered higher 14.2, 29.6 and 53.8% of pods/plant, 12.1, 23.2 and 41.2% grains/pod, 10.6, 24.4 and 34.2% seed index, 37.5, 54.7 and 109.1% grain yield and 29.1, 64.6 and 97.0% stover yield under Fe_5, Fe_{10} and Fe_{15} over control, respectively. Interactive effect of SAR and iron levels on grain and straw yields was found significant and maximum yield was recorded with SAR_{ss} Fe_{15} treatment combination [Table-5]. The higher available nutrient status and favorable soil environment for absorption of nutrients by plant consequently leads to higher photosynthetic efficiency and higher production of assimilates which ultimately resulted in better growth and development of plant in terms of growth and yield attributes of cowpea. Duraisamy and Mani (2001), [24] also reported that application of iron significantly increased pods/plant, seeds/pod and nodules/plant of horse gram as against the control. Similar results were also reported by Yadav (2002)), Gohari and Niyaki (2010) and Jokar, *et al*. (2015) [25-27] reported that in application of Fe fertilizers in different level increased shoot dry-matter yield, root dry matter yield, number of pods per plant, weight of pods and seeds per plant, grain weight per pot, shoot Fe concentration and Fe uptake by cowpea as compared to control treatment.

Conclusion

On the basis of one year field experimentation, it seems quite logical to conclude that growth and yield attributing parameters and yields of cowpea, organic carbon and DTPA-Fe content in soil decreased with increasing level of SAR of soil and increased with increase in level of iron. The yield obtained under S10Fe0 treatment combination was statistically at par to S20Fe10 and S25Fe15 indicating that sodicity tolerance in cowpea can be increased to same extent by applying 37.5 mg/kg $FeSO_4$ 7H2O.

Application of research: Study of yield attributes and yields of cowpea

Research Category: Soil Science

Abbreviations:

DTPA: diethylene triamine penta acetic acid
ESP: exchangeable sodium percentage
SAR: sodium absorption ratio

Acknowledgement / Funding: Author thankful to SKN College of Agriculture, Sri Karan Narendra Agriculture University, Jobner, 303 329, Rajasthan, India

***Research Guide or Chairperson of research: Prof Dr B. L. Yadav**
University: Sri Karan Narendra Agriculture University, Jobner, 303 329, Rajasthan
Research project name or number: PhD Thesis

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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