LONG-TERM EFFECT OF ORGANIC AND INORGANIC FERTILIZER ON BORON FRACTION DISTRIBUTION IN BAJRA MUSTARD COWPEA CROPPING SEQUENCE UNDER TYPICAL USTOCHREPT SOIL

Pooja Kala,
Asst. Professor, School of Agriculture, Graphic Era Hill University,
Dehradun Uttarakhand India

DOI:10.48047/ejmcm/v07/i04/383

Abstract

The experiment on continuous cropping at Anand Agricultural University was employed for the study; the macro- and micronutrient content, soil boron percentage, and critical physical properties of 2019 topsoil samples were analysed and compared to 2014 levels. In 2019, however, scientists not only analysed soil samples from the surface to deep down for biological information, but also for a wide range of soil properties. Traditional analytical techniques were used to examine three kinds of plant and soil samples. For this study, we looked at the effect of long-term application of FYM on fertility levels and the correlation between soil organic carbon and boron content in a bajra-mustard-cowpea (f) cropping cycle.

Keywords: *Organic, Inorganic, Bajra Mustard, Cowpea Cropping Ustochrept Soil.*

1. Introduction

Boron (B) is one of the seventeen trace elements plants need for proper growth and metabolism. Sugar transport, stomatal turgor management, flower development, pollen tube elongation and germination, seed and fruit formation, and many other activities rely on it. It also plays a part in the manufacturing of plant hormones like Indole Acetic Acid.[1]

Dry and semiarid locations have naturally high B levels in soils, and B is often added to irrigation water, therefore B poisoning is a known issue there. In India, some scientists may have overlooked calcareous soils because they believed that B was already abundant in neutral to alkaline soils. However, in the post-green revolution era, yearly withdrawals under intensive cropping systems and replenishments through fertilizers, manures, residues, and irrigation water were primarily used to determine soil B deficit or sufficiency. Even in formerly rich B locations, severe deficits have developed due to a lack of management of soil and crop B levels over the years. [2]

Recent estimates suggest that around 88,000 soil samples had B deficiency. Boron shortage is more common in the acidic soils of Jharkhand (60%), Nagaland (53.3%), Odisha (49.9%), Jammu & Kashmir (48.9%), and Meghalaya (47.9%), but less common in the calcareous soils of Bihar and Gujarat. Recent reports have shown widespread incidence of B deficiencies in the soils of even arid and semi-arid regions that were previously considered adequate in B supply, highlighting the importance of understanding the adsorption-desorption mechanisms and the fractional distribution of soil B, both of which affect B availability to plants.[3-4]

Soil pH, texture, moisture, temperature, organic matter, CEC, and clay mineralogy all influence the quantity of available B to plants. Aluminum and iron oxides, magnesium hydroxide, clay minerals, calcium carbonate, and organic matter are all examples of boron-absorbing surfaces in soils. Amorphous iron oxides and hydroxides are the primary determinants of soil boron adsorption. The unique characteristics of Soil B are influenced by the presence of organic matter. B release from soil surfaces is facilitated by the conferral of reversibility characteristics on the adsorption processes, which seems to be caused by organic matter in the soil shutting off important adsorption sites and preventing any hysteretic activity. Except for oxide bound B, all boron fractions correlated positively with soil pH, OC, and CEC. Boron absorption by soils was shown to increase with boron concentration. Soils high in CEC, clay, and organic carbon also tend to have finer textures, which is beneficial for boron adsorption. The Langmuir adsorption isotherm equation, the Freundlich adsorption isotherm equation, and the phenomenological Keren model may all be used to experimentally characterize boron adsorption processes. [5-6]

At the Rothamsted Experiment station in Harpenden, Herts, England, Lawes and Gilbert started what would become known as the "Rothamsted Classical Experiment" between 1843 and 1856. Based on the success of the Rothamsted experiment, several other groups across the world have begun conducting similar studies. The Long-Term Field Experiment has been studying the long-term impacts of high-input soil management practices including organic and inorganic manuring on crop yields and soil quality since its founding in 1885. Since 1971, the ICAR has provided financing for the All India Coordinated Research Project on Long Term Fertilizer Trials to be carried out throughout all of India's agroclimatic zones. [7]

2. Literature review

Campanelli, G., & Canali, S. (2020) The proportion of soil boron in Latium (Italy) soils treated with mineral fertiliser (ammonium nitrate), compost made from residues from the winemaking process, integrated fertiliser (made up of both compost and ammonium nitrate), and organic mineral fertiliser was examined during a lettuce crop. Only a minor proportion of the soil's total B content was found in the Sol-B and Nsa-B fractions (0.66 to 1.21% for control and integrated fertiliser, respectively), whereas between 86.3 and 88.2% was found in the residual and occluded forms. The increase of B in soil solution (Sol-B and Nsa-B) ascribed to fertilisation was driven mostly by compost and mineral fertilisers.

Janzen, H. H., & Juma, N. G. (2019) studied the correlations between the B fraction distribution in natural soil and a number of soil properties. Karnataka has 10 distinct agricultural climate zones, and 12 surface and subsurface soil samples were collected from each. Most boron was found in its residual form, with amounts ranging from 125 to 567 mg kg1 from the central to the northern dry zone. Freely soluble boron ranged from 0.03 mg kg1 in the southern transition zone to 0.78 mg kg1 in the northern dry zone, while oxide-bound boron was the second most common type, with concentrations ranging from 2.15 in the coastal zone to 8.21 mg kg1 in the eastern dry zone. The northern dry zone has the greatest concentration of total boron (582.3 mg kg1). The most useful easily soluble forms of boron were found to be adsorbed boron, oxide-bound boron, and organically-bound boron across all agroclimatic zones.

Klein, D. P., & Santaro, T. (2018) investigated the factors influencing boron (B) availability and wheat absorption in native soil. Six different treatments were applied: Isolated applications of nitrogen (control), nitrogen plus phosphorus and potassium (NPK), NPK plus farmyard manure (FYM), and NPK alone. The total amount of hot CaCl2-extractable (available) B in the soil, as well as its five different fractions, was calculated. By comparing NPK+FYM therapy to others, it was shown that the easily soluble, particularly adsorbed, and organically bound B fractions were much larger with prolonged usage.

Enwall, K. & Hallin, S. (2017) studied the effects of chemical fertilisers and amendments on boron (B) forms in northern Himalayan acidic Alfisols throughout time. Residual B accounted for a whopping 71.5% of the whole B. The highly correlated B fractions provided evidence of the interconnectedness of the multiple B pools. With the exception of B that was organically bound, depletion was seen throughout the board. Applying farmyard manure (FYM) at the recommended quantities of nitrogen, phosphorus, and potassium resulted in the least loss of oxide-bound boron, surpassing even the liming treatment.

Budak, M., & Akpinar, C. (2016) To ascertain the pattern of boron fraction release in sandy loam B deficiency soils used for growing maize, we conducted a randomised, triple-blind, laboratory incubation experiment. Destructive samples were taken at 0, 7, 15, 21, and 30 day intervals after incubating the soil at field capacity for 30 days. The researchers discovered that the amount of applied boron that was not adsorbed was more than the amount of boron that was left over. It was also determined from the data that residual boron added the most to the overall boron concentration.

3. Methodology

The current study uses a portion of the long-term experiment to evaluate the effects of organic and inorganic fertilization on soil boron fractions, physio-chemical properties, soil enzymatic activities, and changes in soil fertility brought about by fertilization. The study is titled "Long term effect of organic and inorganic fertilizer on distribution of boron fractions in bajra-mustard-cowpea (F) cropping sequence under Typic Ustochrepts soil

3.1 Location of the experimental site

Located in the central Gujarat Agroclimatic zone, at 220°35′ North latitude and 720°55′ East longitude, Anand has an elevation of 45.1 m above mean sea level.

3.2 Methodology of experiments

3.2.1 Collection and preparation of soil samples

Soil samples were taken from each plot following cowpea harvest for this long-term fertility experiment, with depths ranging from 0 to 15 to 30 to 45 to 60 to 90 centimetres. The soil samples were sieved using a 2-millimeter mesh screen and then placed in polythene-lined fabric bags. Preserved soil samples from 2014 and samples obtained after the harvest of cowpea in 2019 were evaluated for their physico-chemical characteristics, including pH, EC, bulk density, porosity, OC, and the status of macro- and micronutrients.

3.3 Experimental details

This research was conducted to learn more about the physical, chemical, and biological aspects of soil after a series of crop rotations, as well as the impact of organic and inorganic fertilization on these factors.

3.4 Methods of analysis

3.4.1 Soil sampling and processing

After cowpea harvest, soil samples were taken at five different depths: 0- 15, 30-45, 45- 60, and 60-90 cm. Soil was collected from four different locations throughout each plot. After collecting soil samples, they were left to air dry before being sieved through a 2 mm mesh in plastic bags. Surface and subsurface soil samples were gathered with little disturbance using a tube auger. The samples were air dried in the shade and then sent to the lab for analysis. An 8mm test sieve is used to separate soil particles of varying sizes. All of the aggregates that made it past the 8 mm sieve but were caught by the 4 mm one. Fresh soil samples were obtained and stored in the fridge at 40 C to analyze its biological properties.

3.4.2 Soil analysis for different parameters

Important soil physical properties, such as bulk density and water holding capacity, as well as chemical properties, such as pH, EC (1:2.5 soil: water ratio), organic carbon (OC), available P2O5, available S, Hot water-soluble B, DTPA extractable micronutrients, and different fractions of boron, were determined from the processed soil samples using the standard method.

3.5 Statistical analysis

The statistical analysis performed in Anand Agricultural University.

4. Results

Using a bajra-mustard-cowpea (F) cropping sequence on Typic Ustochrepts soils, the current study examined the impact of continuous cropping on variations in soil boron fractions, physico-chemical properties, biological activities, and boron content in plant parts under organic and inorganic fertilizer application.

Tables 4.1 and 4.2 detail the effects of FYM and fertility levels and their interaction on the total boron content in grain/seed, straw, and root portion; and the yields of bajra, mustard, and cowpea (F).

The boron content of plant parts harvested after long-term fertilisation with FYM and NP + FYM was considerably enhanced (Table 4.1). By applying FYM at a rate of 10 tonnes per hectare to bajra during the kharif season, the B content of bajra root, mustard seed, and cowpea has steadily grown over time. The increase in dietary vitamin B from FYM treatment was most significant in rabi and summer crops other than bajra root. In most cases, the B content of crops rose by little more than 1 mg kg-1 across all plant sections. All crops had higher B accumulation in their roots, while bajra had 1.5-2.0 times higher than mustard and cowpea.

Table 4.1: Long-term changes in B content at various plant sections in response to FYM and fertility levels in a bajra-mustard-cowpea (F) cropping sequence

Treatments	**PlantBcontent(ppm)**							
	Bajraseed	**BajraStem**	**Bajra root**	**Mustardseed**	**Mustardstem**	**Mustardroot**	**Cowpeastem**	**Cowpea Root**
FYMlevels								
F_0(WithoutFYM)	2.46	5.82	6.62	2.89	15.27	15.68	22.70	23.91
F_1(FYM 10tha^{-1})	2.60	5.92	7.46	3.17	16.29	16.78	23.87	24.92
S. Em±	0.07	0.11	0.15	0.03	0.40	0.40	0.21	0.26
C.D.(P=0.05)	NS	NS	0.47	0.10	NS	0.10	0.62	0.79
FertilityLevels								
FL_0(Control)	2.47	5.83	6.67	2.95	15.59	15.64	22.75	23.95
FL_1(50 %NP)	2.52	5.85	6.93	3.02	15.77	16.18	23.27	24.35
FL_2(100% NP)	2.55	5.89	7.21	3.06	15.85	16.45	23.45	24.59
FL_3(150% NP)	2.58	5.92	7.36	3.10	15.91	16.65	23.69	24.78
S. Em +	0.10	0.16	0.22	0.04	0.57	0.57	0.29	0.37
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Interaction(F x FL)								
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV %	9.42	6.70	7.60	3.58	8.85	8.63	9.07	3.69

Table 4.2 provides information on crop yields for the 2018–19 study periods, which may be used to analyze the effect of FYM and fertility levels on crop productivity.

Data demonstrated substantial variations in bajra grain, straw, and total yield owing to long-term use of FYM (Table 4.2). When compared to no FYM (F0), the grain yield, straw yield, and total yield of bajra were all considerably greater when supplemented with FYM at a rate of 10 t ha-1 (F1). When applied to bajra grain straw and total yield, FYM increased yield by 16.84, 20.69, and 20.22 percent, respectively.

Table 4.2: Bajra, Mustard, and Cowpea (F) Cropping Sequence: Long-Term Effect of FYM and Fertility Levels on Yield

Treatments	Bajrayield (kg ha^{-1})		
	Grain	Straw	Total
FYMlevel			
F_0(WithoutFYM)	849	6051	6900
F_1(FYM10tha^{-1})	992	7303	8295
S. Em±	20	186	183
C.D.(P=0.05)	60	564	555
Fertilitylevel			
FL_0(Control)	839	5908	6747
FL_1(50%NP)	853	6330	7183
FL_2(100%NP)	926	7027	7952
FL_3(150%NP)	1064	7445	8508
S.Em+	28	263	259
C.D.(P=0.05)	85	798	785
Interaction(FxFL)			
C.D.(P=0.05)	NS	NS	NS
CV%	7	10	8

There was a strong correlation between organic carbon in surface soil (0-15 cm) and grain yield (r=0.945**), straw yield (r=0.878**), accessible B (r = 0.877**), and B content in grain, stem, and root (Table 4.3). The strong correlation between these elements and organic carbon indicated that soil organic matter plays a critical role in establishing the soil's B availability. The fact that organic carbon is a source of boron may explain why there is more residual boron in soils with a higher concentration of organic matter. associated outcomes. Boron availability is favourably linked with boron concentrations in the grain (r=954**), stem (r=973**), and root (r=989**).

Several surface soil B values were substantially correlated with organic carbon: (r=0.877**), (r=0.859**), (r=0.874**), (r=0.769**), and (r=0.846**). Three boron fractions (redox-stable boron [RSB], sulfate-accumulating boron [SAB], and organic-rich boron [ORB]) contributed most of the soil's B availability. The close association between these components and organic carbon demonstrates that soil organic matter is a critical component that contributes to the availability of B in soils. There was a strong positive correlation between organic carbon and organically bound B (r = 0.540 **). The correlation between total B and OC was favourable and statistically significant (r = 0.874**). There was no statistically significant relationship (r = 0.375) between boron oxide and organic carbon. Al and Fe oxides and their hydroxides may get occupied by carboxylic and phenolic groups, reducing the number of sites accessible for the adsorption of B species, as a result of the greater organic-matter concentration.

Table 4.3: Seed yield in bajra (0-15 cm) and the correlation between B fractions, OC of surface soil, bajra grain, and B fractions

	GY	SY	Av.B	RSB	SAB	OXB	ORB	RB	TB	Grain B	Stem B	RootB	OC
GY	1	0.945**	0.925**	0.606	0.772*	0.236	0.573	0.812*	0.828*	0.871**	0.932**	0.879**	0.945**
SY	0.945**	1	0.975**	0.605	0.692	0.121	0.659	0.894**	0.901**	0.945**	0.961**	0.953**	0.878**
Av.B	0.925**	0.975**	1	.692	.609	0.048	0.790*	0.842**	0.861**	0.954**	0.973**	0.989**	0.877**
RSB	0.606	0.605	0.692	1	.485	0.027	0.762*	0.338	0.398	0.503	0.604	0.650	0.503
SAB	0.772*	0.692	0.609	0.485	1	0.110	0.169	0.454	0.458	0.577	0.658	0.536	0.594
OXB	0.236	0.121	0.048	0.027	0.110	1	-0.103	0.391	0.418	-0.034	0.083	-0.053	0.375
ORB	0.573	0.659	0.790*	0.762*	0.169	-0.103	1	0.514	0.564	0.657	0.671	0.795*	0.540
RB	0.812*	0.894**	0.842**	0.338	0.454	0.391	0.514	1	0.996**	0.863**	0.859**	0.825*	0.859**
TB	0.828*	0.901**	0.861**	0.398	0.458	0.418	0.564	0.996**	1	0.859**	0.867**	0.837**	0.874**
Grain B	0.871*	0.945**	0.954**	0.503	0.577	-0.034	0.657	0.863**	0.859**	1	0.981**	0.972**	0.860**
Stem B	0.932**	0.961**	0.973**	0.604	0.658	0.083	0.671	0.859**	0.867**	0.981**	1	0.968**	0.919**
RootB	0.879**	0.953**	0.989**	0.654	0.536	-0.053	0.795*	0.825**	0.837**	0.972**	0.968**	1	0.846**

OC	**0.945****	**0.878****	**0.877****	**0.503**	**0.594**	**0.375**	**0.540**	**0.859****	**0.874****	0.860**	0.919**	0.846**	1
*.Correlation issignificant atthe 0.05level (2-tailed)													
**.Correlation issignificant atthe 0.01level (2-tailed)													

Table 4.4: Mustard production, B content in grain, stem, and root, and OC of soil all correlate positively

	GY	SY	Av.B	RSB	SAB	OXB	ORB	RB	TB	Grain B	Stem B	RootB	OC
GY	1	0.974**	0.786*	0.605	0.288	0.461	0.755**	0.806*	0.847**	0.552	0.442	0.733*	0.736*
SY	0.974**	1	0.780*	0.516	0.145	0.351	0.789*	0.823*	0.854**	0.585	0.490	0.758*	0.698
Av.B	0.786*	0.780*	1	0.692	0.609	0.048	0.790*	0.842**	0.861**	0.943**	0.887**	0.989**	.877**
RSB	0.605	0.516	0.692	1	.485	0.027	0.762*	0.338	0.398	0.610	0.570	0.650	.503
SAB	0.288	0.145	0.609	0.485	1	0.110	0.169	0.454	0.458	0.579	0.543	0.536	.594
OXB	0.461	0.351	0.048	0.027	0.110	1	-0.103	0.391	0.418	-0.241	-0.373	-0.053	.375
ORB	0.755*	0.789*	0.790*	0.762*	0.169	-0.103	1	0.514	0.564	0.723*	0.695	0.759	.540*
RB	0.806*	0.823*	0.842**	0.338	0.545	0.391	0.514	1	0.996**	0.716*	0.627	0.825*	.859**
TB	0.847**	0.854**	0.861**	0.398	0.458	0.418	0.564	0.996**	1	0.718*	0.624	0.837**	.847**
Grain B	0.552	0.585	0.943**	0.610	0.579	-0.241	0.723*	0.716*	0.718*	1	0.989**	0.971**	.796**
Stem B	0.442	0.490	0.887**	0.570	0.543	-0.373	0.695	0.627	0.624	0.989**	1	0.929**	0.673
RootB	0.733*	0.758*	0.898**	0.650	0.536	-0.053	0.795*	0.825*	0.837**	0.971**	0.929**	1	0.846**
OC	0.736*	0.698	0.877**	0.503	0.594	0.375	0.540*	0.859**	0.874**	0.769**	0.637	0.846**	1
*.Correlation issignificant atthe 0.05level (2-tailed)													
**.Correlation issignificant atthe 0.01level (2-tailed)													

Table 4.5: Cowpea production, B content in stem and root, and soil organic carbon (OC) all have positive correlations with one another

	SY	Av.B	RSB	SAB	OXB	ORB	RB	TB	Stem B	RootB	OC
SY	1	0.743*	0.318	0.608	-0.350	0.443	0.538	0.520	0.842**	0.791*	0.642
Av.B	0.743*	1	0.692	0.609	0.048	0.790*	0.842**	0.861**	0.977**	0.981**	0.877**
RSB	0.318	0.692	1	0.485	0.027	0.762*	0.338	0.398	0.584	0.685	0.503
SAB	0.608	0.609	0.485	1	0.110	0.169	0.454	0.548	0.552	0.566	0.594
OXB	-0.350	0.048	0.027	0.110	1	-0.103	0.391	0.418	-0.094	-0.146	0.375
ORB	0.443	0.790*	0.762*	0.169	-0.103	1	0.514	0.564	0.755*	0.806*	0.540
RB	0.538	0.842**	0.338	0.454	0.391	0.514	1	0.996**	0.821*	0.761*	0.859**
TB	0.520	0.861**	0.398	0.458	0.418	0.564	0.996**	1	0.826*	0.774*	0.874**
Cowpeastem	0.842**	0.977**	0.584	0.542	-0.094	0.755*	0.821*	0.826*	1	0.984**	0.837**
Cowpearoot	0.791*	0.981**	0.685	0.566	-0.146	0.806*	0.716*	0.774*	0.984**	1	0.793*
OC	0.642	0.877**	0.503	0.594	0.375	0.540	0.859**	0.874**	0.837**	0.793*	1
*.Correlation issignificant atthe 0.05level (2-tailed)											
**.Correlation issignificant atthe 0.01level (2-tailed)											

Several surface soil B values were substantially correlated with organic carbon: (r=0.877**), (r=0.859**), (r=0.874**), (r=0.769**), and (r=0.846**). Three boron fractions (redox-stable boron [RSB], sulfate-accumulating boron [SAB], and organic-rich boron [ORB]) contributed most of the soil's B availability. The close association between these components and organic carbon demonstrates that soil organic matter is a critical component that contributes to the availability of B in soils. There was a strong positive correlation between organic carbon and organically bound B (r = 0.540 **). The correlation between total B and OC was favourable and statistically significant (r = 0.874**). There was no statistically significant relationship (r = 0.375) between boron oxide and organic carbon. Al and Fe oxides and their hydroxides may get occupied by carboxylic and phenolic groups, reducing the number of sites accessible for the adsorption of B species, as a result of the greater organic-matter concentration. The depth of accessible B in the topsoil has a substantial (0.743**) effect on annual straw output.

5. Conclusion

Soil benefited greatly from FYM and fertility treatments from 2014 to 2019, as measured by an increase in bulk density (BD) and maximum water holding capacity (MWHC) at all depths tested. Significant increases in the availability of key nutrients and other chemical features were seen after FYM and fertility treatments as compared to the control, with the greatest increase occurring at the highest fertility level, FL3 (150% NP). In general, the concentration of major nutrients increased with time, independent of therapy, but the concentration of accessible potassium (K) decreased. The highest increases in exchangeable cations, such as Ca and Mg, were seen in treatments F1 (FYM @ 10 t ha-1) and FL3 (NP @ 150% RDF), when FYM was used alone or in combination with inorganic fertilizers.

6. References

1. Alkama, N., Ounane, G., & Drevon, J. J. (2014). Genotypic variation of H+ efflux under P deficiency linked with nodulated-root respiration of N2–Fixing common-bean (Phaseolus vulgaris L.). Journal of plant physiology, 169 (11), 1084-1089.
2. Zamil, K., Rabin& Khatun, A. K. (2016). Combined effect of organic and inorganic fertilizers on the growth and yield of mung bean (Bari Mung 6). International Journal of Scientific and Research Publications, 6 (7), 557-561.
3. Babhulkar, P. S.& Balpande, S. S. (2017). Residual effect of long-term application of FYM and fertilizers on soil properties (Vertisols) and yield of soybean. Journal of the Indian society of soil science, 48 (1), 89-92.
4. Shukla, L. M., & Rattan, R. K. (2014). Effect of applied lime and boron on the availability of nutrients in an acid soil. Journal of Plant Nutrition, 37 (3), 357-373.
5. Anil kumar, K. S., & Sarkar, D. (2015). Soil Boron and Its Fractions in Agro-Climatic Zones of Karnataka. Clay Research, 32 (1),25-33.
6. Satyanarayana, T. (2018). Depth distribution of different forms of sulphur in Vertisols and Alfisols. Journal of the Indian Society of Soil Science, 38 (4), 634-640.
7. Phonglosa, A., & Bhattacharyya, K. (2017). Depth wise distribution of boron in some soils of red and laterite zone of West Bengal, India. International Journal of Current Microbiology and Applied Sciences, 6 (12), 4126-37.

8. Campanelli, G., & Canali, S. (2020). Crop production and environmental effects in conventional and organic vegetable farming systems: The case of a longterm experiment in Mediterranean conditions (Central Italy). Journal of Sustainable Agriculture, 36 (6), 599-619.
9. Janzen, H. H., & Juma, N. G. (2019). Case studies of soil quality in the Canadian prairies: long-term field experiments. Developments in Soil Science, 25, 351-397.
10. Klein, D. P., & Santaro, T. (2018) Soil dehydrogenase activity. Soil Science, 93, 371-376.
11. Enwall, K. & Hallin, S. (2017). Soil carbon quality and nitrogen fertilization structure bacterial communities with predictable responses of major bacterial phyla. Applied Soil Ecology, 84, 62-68
12. Budak, M., & Akpinar, C. (2016). Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semiarid Mediterranean soil conditions. Geoderma, 160 (2), 236-243.