Proceedings of ICEM'10

2nd International Conference on Environmental Management
(October 25th – 28th, 2010)

VOLUME – I

Climate Change Vulnerability Analysis: Tools and Technologies

Climate Change Impact and Vulnerability

Climate Change Influence on Water Resources

Editors
M. Anji Reddy
T. Vijaya Lakshmi

Jawaharlal Nehru
Technological University Hyderabad, INDIA

BS Publications

Editorial Board : ICEM'10

Water use Efficiency Enhanced through Balanced Nutrient Management - A Case Study from Rajasthan

Girish Chander, Suhas P Wani, KL Sahrawat and TP Mathur

International Crop Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru - 502324, Andhra Pradesh, India

ABSTRACT

Nutrient deficiencies in addition to water shortage are holding back the potential to enhance productivity of the rainfed systems in the semi arid tropics (SAT) and is one of the main reasons for poor utilization of available water and thereby low water use efficiency. The vulnerability of farmers to anticipated changes in patterns of supplies of natural resources particularly water shortage due to climate change requires optimum utilization of water resources. In soil sample analysis from farmers fields in the semi arid regions of Rajasthan, available sulphur, boron and zinc varied across farmers fields from 1.90 to 274, 0.08 to 2.46 and 0.06 to 28.6 mg kg^{-1}. The findings surprised with widespread deficiencies of sulphur, boron and zinc in addition to nitrogen and phosphorus. Farmer participatory experiments were conducted in the semi arid regions of Rajasthan on inclusion of deficient secondary and micronutrients in the fertilizer recommendations for crop production along with improved cultivars. The integrated approach of soil and crop management recorded best yields by way of improved water use efficiency in maize (2.42 times), pearl millet (2.51 times), and soybean (1.83 times). These findings confirmed that the inclusion of deficient secondary and micronutrients in fertilizer recommendations particularly with improved cultivars is a step forward in making the production systems robust and resilient to effectively utilize the scarce water resources for food production.

KEYWORDS

Water use efficiency, productivity, secondary and micro-nutrients, climate change, sulphur, boron, zinc.

INTRODUCTION

Rain-fed agriculture in India is practiced on about 60% of cultivated area (Wani et. al., 2008). Current productivity of the rain-fed agriculture is quite low (1 to 1.5 t ha^{-1}) as against a potential of 2.5 to 7.0 t ha^{-1} and thus are target regions for increasing production in future (Fischer et al., 2009, Wani et al., 2003). Rajasthan is the largest state under rain fed agriculture in India where more than 60% of the total area falls under arid regions. Water shortage is a major constraint for food production where Rajasthan has only 1.16 % of the water resources of the country as against its share of 11% in the total geographical area. The annual rainfall ranges from 150 mm in the western parts of the state to 900 mm in the east. The statistics point out decline of groundwater in the state at an alarming rate which poses a grim scenario. Climate change may further aggravate the problem, due to observed reductions in rainfall in the lower tropical latitudes (Zhang et al., 2007). Some experts are predicting further declines in rainfall and amplification of extreme events (IPCC, 2007). Hence, producing more food with less water by way of increasing rain water use efficiency in the state of Rajasthan is important for achieving food security and improving the livelihoods of poor farmers. The predominant soils in these regions are Aridisols which are poor in water holding capacity. Most importantly, dryland soils are multinutrient deficient and so need proper nutrient management strategies (Srinivasarao and Vittal, 2007) to get good yields on sustainable basis. Stratified soil sampling of fields on a toposequence in the benchmark watersheds in Rajasthan revealed widespread deficiency of multiple nutrients particularly Zn (67-100%), B (72-100%) and S (72-100%) along with N and P, which are mainly limiting the yield potential (Sahrawat et al., 2007; Srinivasarao et. al., 2008). Keeping this in view, the present intervention so aimed to have higher crop production per drop by demonstrating productivity enhancement by inclusion of high yielding cultivars and addition of deficient secondary and micronutrients.

MATERIALS AND METHODS

Four hundred twenty one soil samples were collected from farmers' fields in Alwar, Banswara, Bhilwara, Bundi, Dungarpur, Jhalawar, Sawai Madhopur, Tonk and Udaipur districts by adopting stratified soil sampling method (Sahrawat *et al.*, 2008) and analyzed for available-S, B, Zn, P, K and organic carbon by standard procedures. Soil analysis results were taken as the base for conducting farmer participatory research & development (PR&D) trials on application of deficient sulphur, boron and zinc along with nitrogen and phosphorus in the rainfed target districts of Rajasthan during the rainy season of 2009. Farmers' fields served as the sites of learning. Farmers involvement in soil sampling, sharing results and conducting research trials for development was particularly emphasized for their understanding and adoption of this science led intervention for real impact on ground. The treatments under the study were, (i) T_1= Farmers practice comprising of application of sub-optimal N and P (ii) T_2=Farmers practice + Improved cultivar (iii) T_3=Improved cultivar + Balanced nutrition. Balanced nutrition treatment contained 60:20:0:30:0.5:10 kg N, P, K, S, B and Zn per ha, respectively for all crops except legumes which received 20 kg N ha^{-1}(Basal) along with the same quantities of other nutrients. Application of all the nutrients except N was made as basal. Fifty per cent N was added as basal and the remaining in two equal splits at one month interval. The final crop yields were recorded. The rainfall data was used to work out the water use efficiency in production of different crops taking into consideration the additional irrigation applied. Based upon the amount of water used for crop production through irrigation and rainfall, the water use efficiency was worked out and expressed as kg mm^{-1} ha^{-1}. The districts Dungarpur, Tonk, Sawai Madhopur, Bundi, Bhilwara, Jhalawar and Udaipur received 697.9, 287.8, 329.8, 366.7, 341.2, 604.9 and 569.6 mm rainfall during the crop growth phase in rainy season, 2009 The benefit from adoption of improved technology was also evaluated in terms of benefit:cost (B:C) ratio by dividing additional net returns with additional cost.

RESULTS AND DISCUSSION

Soil Analysis

The soil analysis of farmers fields showed that organic carbon, available phosphorus and potassium ranged from 0.09 to 2.37%, 0.20 to 44 mg kg^{-1} and 14 to 1358 mg kg^{-1}, respectively (Table 1). While available sulphur, boron and zinc varied from 1.90 to 274, 0.08 to 2.46 and

0.06 to 28.6 mg kg^{-1}, respectively. Majority fields (>50%) showed widespread deficiency of secondary nutrient sulfur and the micronutrients boron and zinc. The arid and semi-arid climate of the state results into rapid mineralization of organic matter content thereby facilitating leaching losses of associated sulfur and other micronutrients in addition to crop removals and subsequent manifestation of nutrient deficiencies. The observed pH range in the soil analysis (6.3 to 10.2) was also on higher side which may also be another reason for micronutrient deficiencies. The soils were in general adequate with respect to available K. The soil analysis results are in line with those reported by Sahrawat et al. (2007) and Srinivasarao et. al. (2008).

The obseved widespread deficiencies of sulphur, boron and zinc are mainly limiting productivity in the target districts and formed the basis to include the deficient secondary and micro nutrients in addition to N and P in fertilization plan to combat land degradation and boost crop yields and water use efficiency.

Table 1 Available S, B and Zn status of soils in farmers' fields in different districts of Rajasthan

District	No Of Farmers	OC (%)	Av P (mg kg^{-1})	Av K (mg kg^{-1})	Av S (mg kg^{-1})	Av B (mg kg^{-1})	Av Zn (mg kg^{-1})
Alwar	30	0.33-0.66	0.5-44.0	53-515	4.5-17.2	0.20-0.68	0.20-2.00
Banswara	30	0.28-1.05	1.0-35.0	31-418	2.4-22.0	0.10-0.54	0.26-2.60
Bhilwara	30	0.32-1.87	0.8-27.0	33-460	4.0-44.9	0.32-1.30	0.16-2.30
Bundi	36	0.18-1.17	0.9-20.1	23-563	3.3-51.0	0.10-0.98	0.20-1.78
Dungarpur	99	0.48-1.99	1.0-28.2	34-240	4.0-31.3	0.28-1.50	0.88-14.1
Jhalawar	30	0.46-1.15	0.9-22.6	51-1358	1.9-78.0	0.22-1.36	0.40-3.40
Sawai Madhopur	44	0.16-0.70	0.2-11.8	44-438	3.1-26.6	0.20-2.18	0.34-28.6
Tonk	78	0.09-1.11	0.2-28.2	14-243	2.3-29.8	0.08-2.46	0.06-11.9
Udaipur	44	0.25-2.37	2.6-41.0	52-288	3.2-274.0	0.22-1.50	0.70-3.92
All districts	421	0.09-2.37	0.2-44.0	14-1358	1.9-274.0	0.08-2.46	0.06-28.6

Yield

The pooled data from 87 farmer participatory research and development trials conducted during rainy season, 2009 on water productivity in maize crop in semi arid regions of Rajasthan, comprising Tonk, Sawai Madhopur, Bundi, Bhilwara, Jhalawar and Udaipur (Figure 1) showed that only adoption of improved cultivar along with farmers' practices got an increase in productivity by 1.46 times over farmers cultivar. Further, improved cultivar along with balanced nutrition resulted in to maximum yield increase by 2.40 times. The shifting from farmers practice to integrated genetic and natural resource management approach resulted Rs 24318/- additional returns as against additional cost of Rs. 4250/- on seed and fertilizers, thus a very favorable B:C ratio of 5.72. The adoption of integrated genetic and natural resource management (IGNRM) approach in rainfed areas is thus the way forward to make the Grey to Green Revolution a reality (Rego et al., 2005).

A similar increase in yield was recorded in pearl millet trials conducted in the districts of Tonk and Sawai Madhopur districts. The pooled data for 27 farmer participatory trials showed 1.56 times increase with only adoption of improved cultivar over farmers one while 2.48 times increase with the use of best bet management over farmers practices. An analysis of additional net returns (Rs. 10344) against additional cost (Rs. 3180/-) shows the adoption of integrated approach the best alternative with B:C ratio of 3.25. The science led cultivation of drought tolerant pearl millet may thus play an important role in improving the livelihoods of farmers in particularly Tonk and Sawai Madhopur regions which receive very less rainfall.

In soybean crop, the respective productivity improvement was 1.32 times at 0.95 t ha^{-1} due to improved cultivar and 1.83 times at 1.32 t ha^{-1} due to conjoint adoption of improved cultivar and balanced nutrition over the farmers practice (0.72 t ha^{-1}). The best bet approach recorded additional returns of Rs. 9536/- as against additional cost of Rs. 5000/- over and above farmers practice, thus suggesting the integrated approach economically viable (BC ratio=1.91) in short run also in addition to making systems robust for future food security.

These findings are in line with earlier ones (Rego et al., 2005: Rao et. al., 2009) which shows rainfed crops responding beneficially to soil test based application of deficient secondary and micronutrients, thus confirming these deficiencies as limiting factors in holding back the crop yield potential.

Fig. 1 Effect of improved cultivar and balanced nutrition on crop yields (t ha^{-1}) during rainy season 2009.

Water Use Efficiency

The balanced nutrition comprising of S, B & Zn along with N & P substantially increased water use efficiency (WUE) in maize in comparison to farmer's practice of application of only sub-optimal N & P (Figure 2). The WUE of maize crop under farmers practices was 4.62 kg mm^{-1} ha^{-1} which improved to 6.82 kg mm^{-1} ha^{-1} with improved cultivar and further to 11.18 kg mm^{-1} ha^{-1} with improved cultivar and balanced nutrition. The increase in WUE with the introduction of improved cultivar over farmers ones was 1.48 times, thereby indicating the significance of improved variety in crop production to best utilize the limiting water resources. However, the maximum increase of 2.42 times was recorded with the adoption of balanced nutrition along with improved cultivar, thus confirming the role of integrated management involving the deficient secondary and micronutrients in realizing the potential and getting the maximum WUE. Singh and Chaudhary (2006) also recorded the role of cultivar and application of deficient S in increasing water use efficiency by chickpea. The integrated soil and crop management involving improved crop varieties and soil fertility management, with a purpose to increase proportion of water balance as productive transpiration, are one of the most important rainwater management strategies to improve yields and water productivity (Rockstrom et al., 2010).

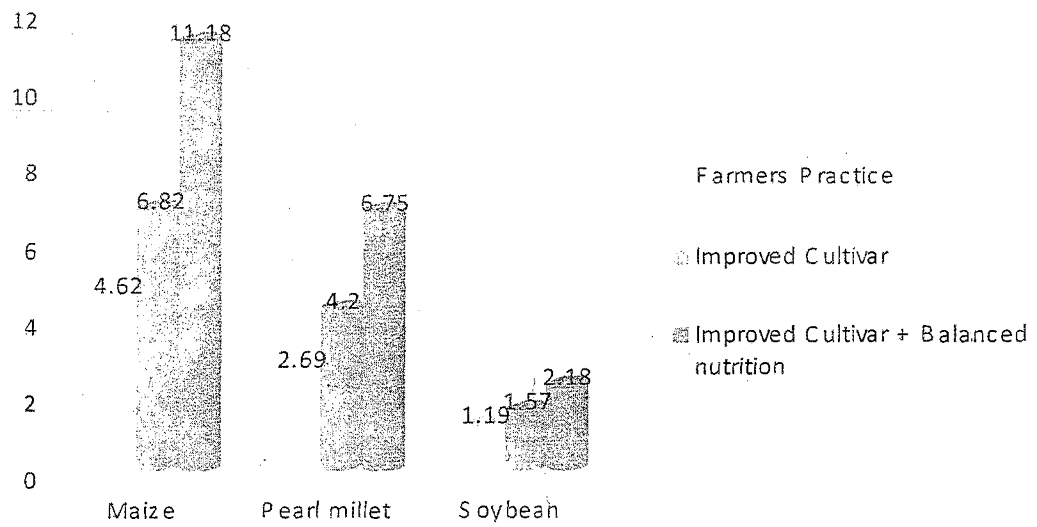

Fig. 2 Effect of improved cultivar and balanced nutrition on water use efficiency of crops (kg mm^{-1} ha^{-1}) during rainy season 2009.

Similarly in pearl millet crop the farmers practice recorded a WUE of 2.69 kg mm^{-1} ha^{-1} which improved to 4.20 kg mm^{-1} ha^{-1} resulting 1.56 times increase. As in maize, the maximum WUE (6.75 kg mm^{-1} ha^{-1}) realized as a result of adopting integrated approach of including improved cultivar and balanced nutrition together which means 2.51 times increase over farmers practice.

Soybean crops also recorded maximum WUE of 2.18 kg mm^{-1} ha^{-1} with improved cultivar and balanced nutrition as against farmers practice (1.19 kg mm^{-1} ha^{-1}) , thus recording an increase of 1.83 times, over the farmers practice.

CONCLUSION

From findings of the present study in Rajasthan, it can be inferred that deficient secondary nutrient S and micronutrients B and Zn are holding back the crops to realize yield potential and efficient use of existing available water. Keeping in view the present soil fertility scenario in the state, it is recommended to apply S, B and Zn to get higher yields and improve water use efficiency of scarce existing water resources and maintain soil productivity on a sustainable basis.

ACKNOWLEDGEMENT

The support from Ministry of Water Resources, Government of India and Sir Dorabji Tata Trust, Mumbai, India for undertaking the presented work is gratefully acknowledged.

REFERENCES

Fischer, G., Velthuizen, H.V., Hizsnyik, E., Wiberg, D. 2009. Potentially obtainable yields in the semi-arid tropics. Global theme on agroecosystems report no. 54, Patancheru-502324, Andhra Pradesh, India, International Crop Research Institute for the Semi Arid Tropics, 68 pp.

IPCC (International Panel on Climate Change). 2007. Climate Change 2007. Fourth assessment Report. Cambridge University Press, Cambridge, UK.

Rao, C. S., Wani, S. P., Sahrawat, K. L., Rajasekharao, B. 2009. Nutrient management strategies in participatory watersheds in semi arid tropical India. Indian Journal of Fertilisers 5 (12), 113-128.

Rego, T.J., Wani, S.P., Sahrawat, K.L., Pardhasaradhi, G. 2005. Macro-benefits from boron, zinc and sulfur application in Indian SAT: A step for Grey to Green Revolution in agriculture. Global Theme on Agroecosystems Report no. 16, Patancheru 502 324, Andhra Pradesh, India, International Crops Research Institute for the Semi-Arid Tropics. 24 pp.

Rockstrom, J., Karlberg, L., Wani, S.P., Barron, J., Hatibu, N., Oweis, T., Bruggeman, A., Farahani, J., Qiang, Z. 2010. Managing water in rainfed agriculture-the need for a paradigm shift. Agricultural Water Management 97, 543-550.

Sahrawat, K. L., Rego, T.J., Wani, S. P., Pardhasaradhi, G. 2008. Stretching soil sampling to watershed: Evaluation of soil-test parameters in a semi-arid tropical watershed. Communications in Soil Science and Plant Analysis 39, 2950-2960.

Sahrawat, K. L., Wani, S. P., Rego, T. J., Pardhasaradhi, G., Murthy, K. V. S. 2007. Widespread deficiencies of sulphur, boron and zinc in dryland soils of the Indian semi-arid tropics. Current Science 93 (10), 1428-1432.

Singh, Y. P., Smita Chaudhary. 2006. Response of varieties to sources of phosphorus and irrigation schedule on growth, quality, yield, sulphur uptake and water use by chickpea (*Cicer arietinum* L.). Research on Crops 7(1), 84-87.

Srinivasarao, C., Vittal, K. P. R. 2007. Emerging nutrient deficiencies in different soil types under rainfed production systems of India. Indian Journal of Fertilisers 3 (5), 37-44.

Srinivasarao, C., Wani, S. P., Rego, T. J., Pardhasaradhi, G., Rangu Rao, Somnath Roy, Chourasia, A. K. 2008. Enhanced productivity and income through balanced nutrition in Madhya Pradesh and Rajasthan Watersheds. Indian Journal of Dryland Agricultural Research and Development 23 (2), 1-5.

Wani, S.P., Pathak, P., Jangawad, L.S., Eswaran, H., Singh, P. 2003. Improved management of vertisols in the semiarid tropics for increased productivity and soil carbon sequestration. Soil Use and Management 19(3), 217-222.

Wani, S.P., Sreedevi, T.K., Sahrawat, K.L., Ramakrishna, Y.S. 2008. Integrated watershed management – a food security approach for SAT rainfed areas. Journal of Agrometeorology 10 (1): 18-30.

Zhang, X., Zwiers, F.W., Hegerl, G.C., Lambert, F.H., Gillette, N.P., Solomon, S., Stott, P.A., Nozawa, T. 2007. Detection of human influence on twentieth-century precipitation trends. Nature 448, 461-466.