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Fertility Status of Soils and Improved Crop Productivity through Balanced Nutrition in Rainfed Watershed of India - a GIS based Study

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Abstract— *Rain-fed agriculture productivity is crucial for food security and economy of the state. To characterize the fertility status of soils under dry-land agriculture in the semi-arid regions, 110 soil samples were collected from Nagulapally-Konapur Model Watershed area in Medak district of Telangana to diagnose the deficiencies of macronutrients like Potassium, Sodium and Sulphur and micronutrients like Boron and Zinc. A summary of the chemical analysis of soil samples covering the watershed area showed that the farmer's fields sampled had a wide range in pH and EC and they were low-to-moderate in organic carbon, generally adequate in exchangeable potassium and sodium. However, the most revealing results on soil chemical analysis were the widespread deficiencies of levels of extractable phosphorous (P), sulphur (S), boron (B) and zinc (Zn) in the samples. GIS mapping of the estimated fertility parameters was carried out using Arc GIS software to understand the occurrence of deficiencies of micronutrients over the watershed area under study. On-farm participatory trials were conducted for selected rainfed crops to study the impact of balanced nutrition (BN) on crop productivity over farmers practise (FP).*

Keywords— Agriculture, Fertility, Macronutrients, Micronutrients, GIS.

I. INTRODUCTION

Semi Arid Tropics (SAT) regions spread over 1.16 billion hectares in the developing world, are densely populated and poverty stricken, largely as a result of dependence of the economy and livelihoods on subsistence agriculture (Srinivasarao et. al., 2008). Soils in the Indian SAT are marginal compared to irrigated soils. Poor soils are brought under cultivation due to population pressure. It is, however, recognized and emphasized that the productivity of SAT soils is low due to water shortage. Apart from water shortage, low fertility is also an issue because it constraints crop productivity in the SAT regions of India; but in practice the deficiencies of major nutrients (N and P) are considered important. (Sahrawat et.al. 2007). Rain-fed agriculture productivity is crucial for food security and economy of the state. To achieve foods security, minimize water conflicts and reduce poverty it is essential to increase productivity of rainfed systems by harnessing the existing potential (Wani et al., 2003a).

To analyse the general fertility status of soils in rain-fed systems and to study the change in economic crops in response to addition of deficient nutrients over farmer's practice, soil samples were collected from Nagulapally-Konapur Model Watershed, Medak District, Telangana. Based on the soil test results, on-farm participatory trials were planned and conducted with the farmers to evaluate and demonstrate the effects of balanced nutrition on crop productivity.

II. METHODOLOGY

Soil samples from agricultural fields in Nagulapally and Konapur villages of the watershed under study were collected by adopting stratified random sampling along the toposequence. To diagnose the deficiencies of macronutrients like Potassium, Sodium and Sulphur and micronutrients like Boron and Zinc in the soils of watersheds under study, soil testing was carried out using following methods –

Table.1: Different methods used for diagnosis of fertility parameters of soil samples

Soil Property	**Description**
pH	Soil to water ratio of 1:2 using glass electrode
EC	Same as above, using EC meter
Organic Carbon (OC)	Wet dichromate oxidation (Nelson & Sommers 1996)
Avail P	Olsen P (0.5M $NaHCO_3$,pH 8.5) (Olsen & Sommers 1982)
Avail Na & K	1N ammonium acetate (Helmke & Sparks 1996)
Avail S	$CaCl_2$/MCP extraction (Tabatabai 1996)
Avail Zn	DTPA extractable Zn (Lindsay and Norvell 1978)
Avail B	Hot water extractable B (Keren 1996)

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Arc GIS 9.3 software was used for spatial and non-spatial database generation and for preparation of spatial distribution maps by inverse distance weighted (IDW) method. Based on the attribute database of the soil quality, the mapping of physico-chemical analysis was carried out and area under nutrient deficiency was calculated using Reclassify tool in Arc GIS 10.3 in which the critical limits of the nutrients were added in IDW maps to class the deficient and non-deficient soil samples. Based on the soil testing analysis, soil-test based fertilizer recommendations were developed at block/village level for balanced nutrient management. Full dose of a nutrient was recommended if >50% deficiency was observed and half dose of nutrients if deficiency was observed <50% based on the critical limits of various nutrients in the soil. On-farm participatory trials were conducted with the farmers to evaluate and demonstrate the effects of balanced nutrition on crop productivity in rainy season. Common rainfed crops such as tomato, chillies, turmeric, cotton, paddy and red gram that are usually grown in the watershed are were selected for the treatments.

Two treatments were conducted -

1. Farmer's practice (FP, application of N, P & K)
2. Balanced nutrition (BN, applications of N, P, K plus S, B & Zn)

DAP (diammonium phosphate) – N & P, Gypsum – S, Zinc Sulphate – Zn, Agribor – B

III. RESULTS AND DISCUSSIONS

The soil test results for pH, EC, Organic C, extractable P, K, Na, S, B and Zn of soil samples collected from farmer's fields in the semi-arid watershed comprising of two villages Nagulapally and Konapur located in Medak district of Indian state of Telangana (110 farmer's fields) showed that the results varied with villages in the watershed and had a wide range in soil chemical characteristics analyzed to evaluate the fertility status of farmer's fields. The farmer's fields that are selected and sampled for soil testing are shown in figure 5.12 with map of watershed prepared in Arc GIS 10.3.

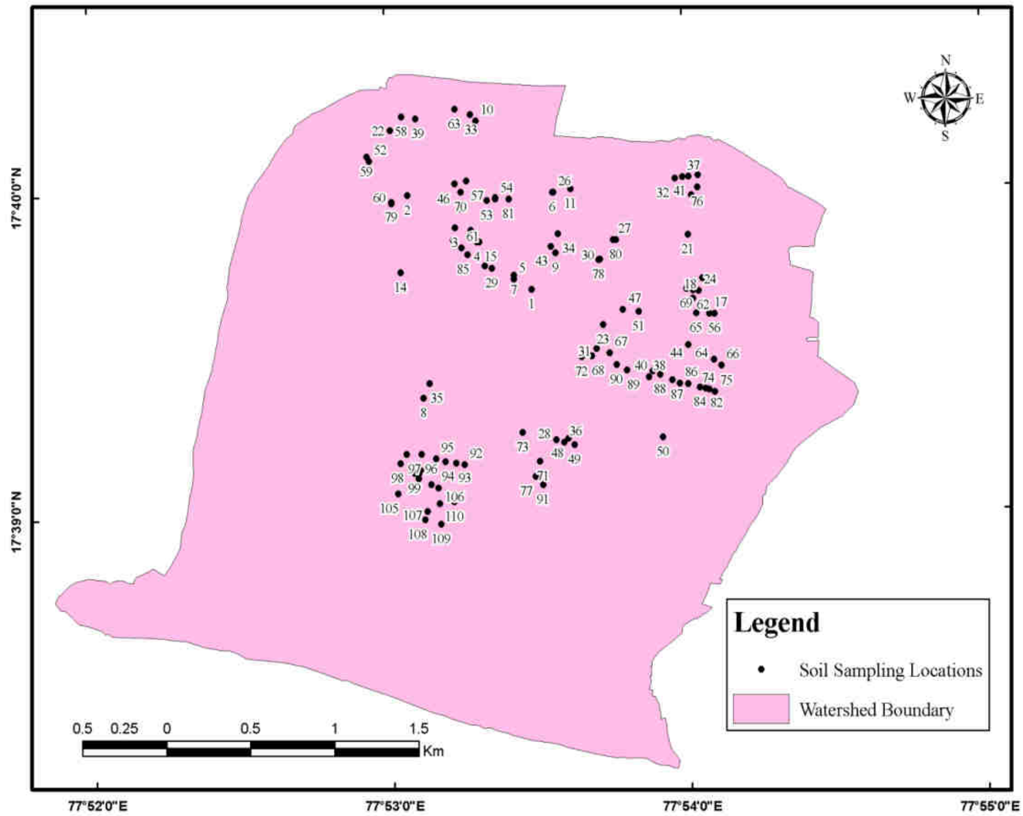

Fig.1: Soil sampling locations in Nagulapally-Konapur Model Watershed, Medak, Telangana

The overall results of soil samples collected from 110 farmer's fields in Nagulapally-Konapur watershed of Medak district are presented in Table 2. The statistical measures range, mean, % of samples deficient and area of watershed under deficiency are shown below. The estimated soil fertility parameters were taken into GIS environment and the extent of occurrence of deficiencies of essential nutrients were mapped spatially to identify the deficient and critical fields in the watershed.

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Table.2 Soil fertility status of farmer's field in Nagulapally-Konapur model watershed

Sample Count – 110									
Parameter	**pH**	**EC dSm^{-1}**	**Org C %**	**Ols-P $mgkg^{-1}$**	**Exch-K $mgkg^{-1}$**	**Exch-Na $mgkg^{-1}$**	**Avail-S $mgkg^{-1}$**	**Avail-B $mgkg^{-1}$**	**Avail-Zn $mgkg^{-1}$**
Range	5.1-8.7	0.1-0.8	0.1-1.6	0.1-13.6	73-544	50-492	2.5-925	0.2-1.5	0.5-80
Mean	8.04	0.17	1.17	2.02	247.40	123.83	18.06	0.61	2.07
% deficiency			4	95	0	0	84	53	42
Area Deficiency (ha)			0.57	1181	0	0	972.35	441.48	349.85

The pH of the soil samples ranged from 5.1 – 8.7 indicating some samples with acidic pH with a mean of 8.04 showing alkaline nature of soils (Figure 2). The EC content reflects the amount of soluble salts present in the soils. The EC values ranged from 0.1dSm^{-1} to 0.8 dSm^{-1} with mean of 0.17 dSm^{-1} (Figure 3). Very low deficiency of only **4%** was observed with organic C concentration which is generally considered as source of N. The organic C values ranged from 0.1% to 1.6 % with mean of 1.17%. Figure 4 shows spatial distribution map of organic carbon with **0.57ha** area under deficiency. Phosphorous deficiency was prominent in the watershed with **95%** of fields showing P deficiency. This may be due to excessive use of organic phosphatic fertilizers by the farmer's inputs. The extractable P values ranged from 0.1$mgkg^{-1}$ to 13.6$mgkg^{-1}$ with average of 2.02$mgkg^{-1}$. Out of 1185ha area of watershed, **1181ha** is observed to be deficient with P content (Figure 5). The extractable K and Na concentrations were in sufficient amounts and all the farmer's fields analyzed showed adequate amounts and as such were not a problem in any of the soil samples. The extractable K ranged from 73$mgkg^{-1}$ to 544 $mgkg^{-1}$with mean of 247.40$mgkg^{-1}$ (Figure 6). Na concentrations in the soil samples fluctuated from 50$mgkg^{-1}$to 492$mgkg^{-1}$with an average value of 123.83$mgkg^{-1}$. Figure 7 shows the spatial distribution map of Na with adequate amounts in all the farmer's fields. In addition to macronutrient deficiency, the analysis results showed a widespread deficiency of secondary and micronutrients in terms of S, B and Zn. Sulphur deficiency was found in majority of the fields with **84%** of total samples have low concentrations of extractable S. The sulphur values ranged between 2.5$mgkg^{-1}$ to 925$mgkg^{-1}$ with mean of 18.06$mgkg^{-1}$ (Table 2). About **972.35ha** of area of watershed was observed under S deficiency shown with light and dark color codes in figure 8. **53%** of samples were estimated with boron deficiency with boron concentration ranging from 0.2$mgkg^{-1}$-1.55$mgkg^{-1}$ with mean concentration 0.61$mgkg^{-1}$. A total of **441.48ha** of area out of 1185ha of total watershed area was found to be deficient with boron micronutrient (Figure 9). As compared to other micronutrients, Zn concentration deficiency was observed low showing **42%** of soil samples analyzed were deficient. Very low values fluctuating between 0.55$mgkg^{-1}$ to 805$mgkg^{-1}$ with average Zn concentration of 2.07$mgkg^{-1}$ was observed and about **349.85ha** of total area was found to b deficient. Figure 10 clearly demonstrates the spatial distribution of the regions of farmer's field having Zn deficiency.

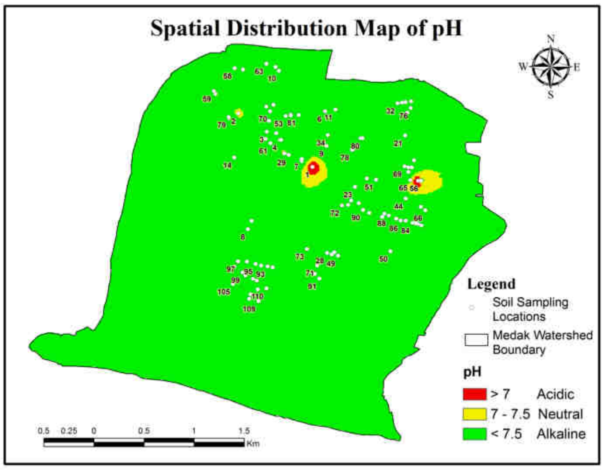

Fig.2

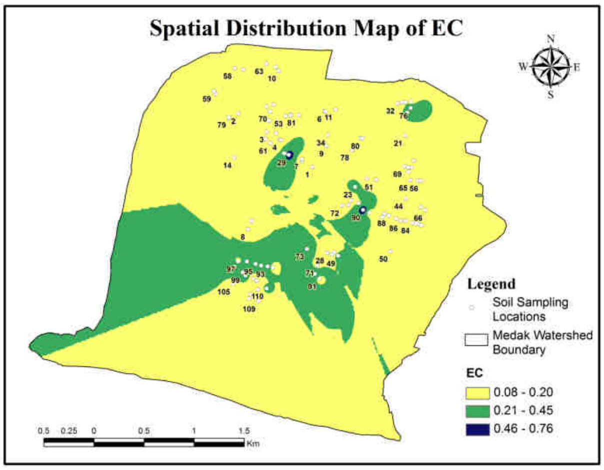

Fig.3

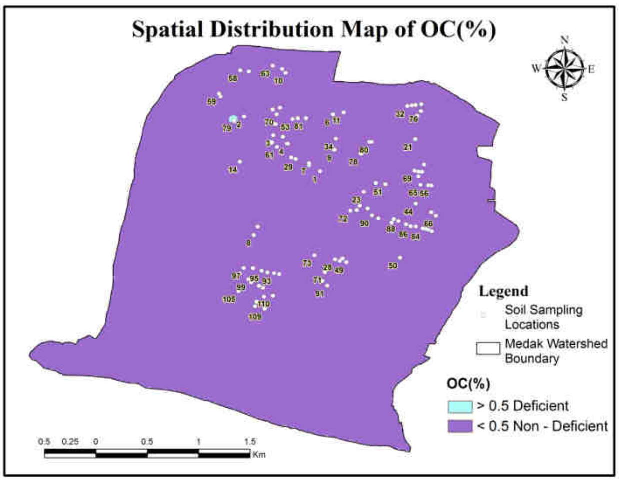

Fig.4

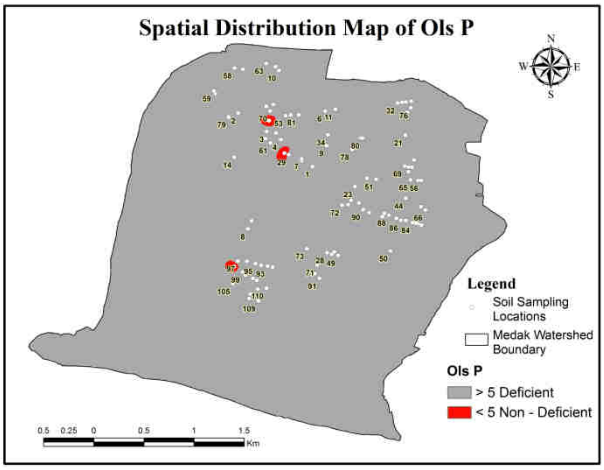

Fig.5

The results clearly highlights the wide range of macro, secondary and micronutrients over the study region and widespread deficiencies of these essential nutrient that may have impact on the production and productivity of the diverse range of crops that are commonly grown on these soils.

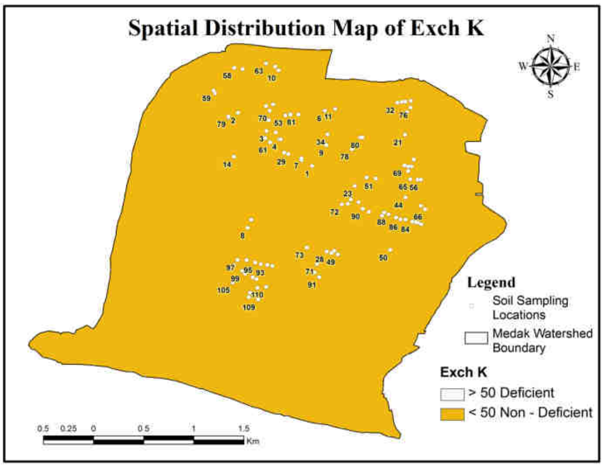

Fig.6

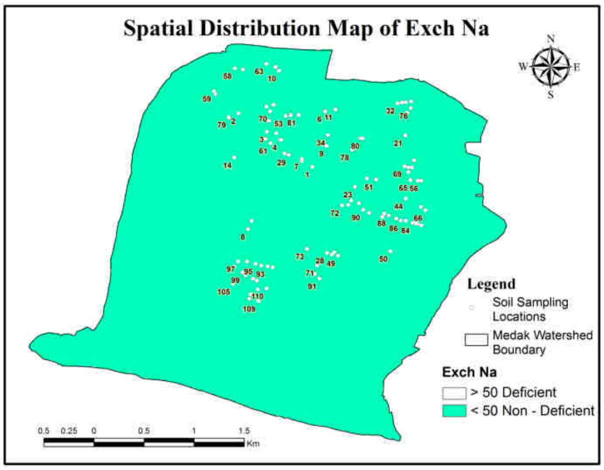

Fig.7

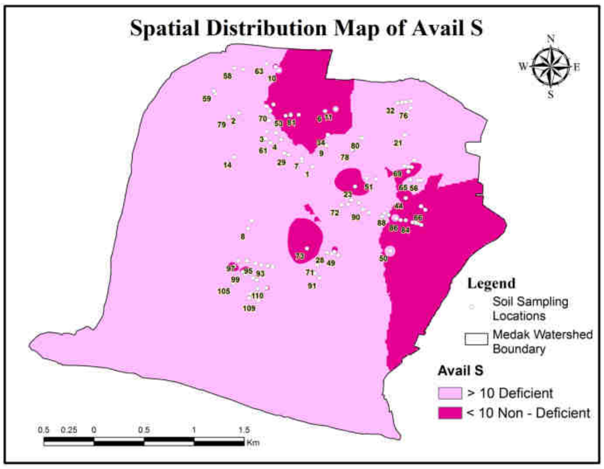

Fig.8

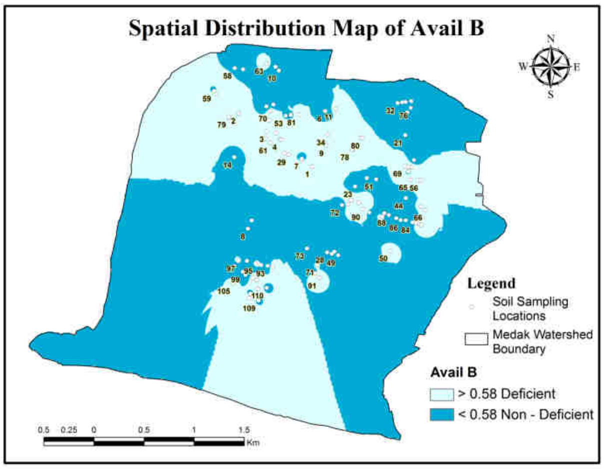

Fig.9

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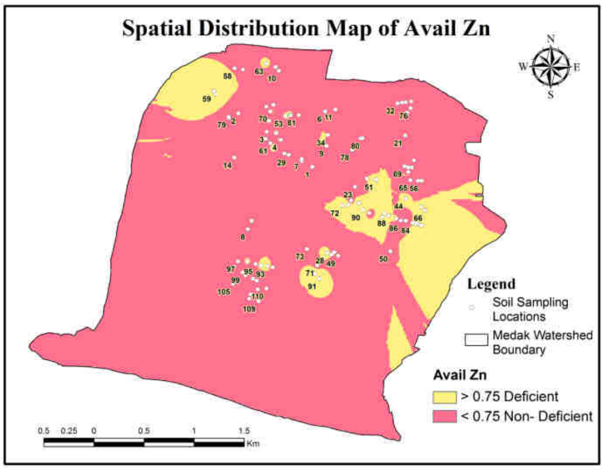

Fig.10

For crop response study, on farm trials were planned and conducted with participation of farmer's. Based on the soil testing results, deficient nutrients were broadcasted and the response of various crops to balanced nutrient management over the farmer's inputs was studied and evaluated in terms of increase in yields of selected crops. Vegetables as tomato, chillies, turmeric and other common crops in the region as cotton, paddy and red gram were selected as test crops to carry out the trials.

Table 3 shows the detail information of the beneficiaries of balanced nutrition i.e. the farmer's on which the trial plots were conducted, crops selected, crop responses over both the treatments and enhancement in yields.

Table.3: Responses of crops to balanced nutrition over farmer's practice at Nagulapally-Konapur Model Watershed, Medak, Telanagana

Sr. No	Name of the Beneficiary	Crops	Crop yield (kg/ha)			% Increase
			Farmer's Practice	Balanced Nutrition	Yield Increase	
1	Dakuri Anjanna	Tomato	1200	1950	750	63
2	Saale Pandu	Chillies	900	1320	420	47
3	Karkani Balaiah	Turmeric	1510	1880	370	25
4	Mogudampally Veeranna	Cotton	1700	2650	950	56
5	Patolla Baswaraj	Paddy	1470	2100	630	43
6	Md Maqbul	Redgram	900	1600	700	39

Response of crops due to appication of S, B and Zn along with N, P and K over farmer's practise (application of only N,P and K) in tomato showed remarkable significant increase of **63%** in yields of tomato. The vegetable yield increased from 1200kgha^{-1} with farmers practice to 1950 kgha^{-1} yields with balanced nutrition treatment. Chillies yielded **47%** more with FP + S, B and Zn application than farmer's practice in fields of farmer Saale Pandu in Nagulapally village. The crop yields were recorded at 900kgha^{-1} for farmer's treatment with increasing to 1320kgha^{-1} in balanced nutrition treatment showing 420kgha^{-1} increase in yields. Turmeric cultivation increased the yield from 1510 kgha^{-1} with farmer's practise treatment to 1880kgha^{-1} yields for balanced nutrient mangement. **25%** increase in turmeric yields was recorded over farmer's practise. An impressive increase in yield was observed with Mogudampally Veeranna farmer in Nagulapally for cotton crop being benefited with **56%** increase in yields with balanced nutrition over farmer's practice (Figure 11). The cotton yield were recorded at 1700kgha^{-1} for traditional farmer's practise 2650kgha^{-1} Response with paddy crop benefited the Patolla Baswaraj farmer in Nagulapally village showing increase of **43%** in crop yields recorded at 1470 kgha^{-1} for farmer's treatment to 2100 kgha^{-1} response to balanced nutrient management. Grain yield of redgram increased from 900kgha^{-1} to 1600kgha^{-1} showing increase in yields upto **39%** in Md Maqbul farmer in Konapur village of watershed.

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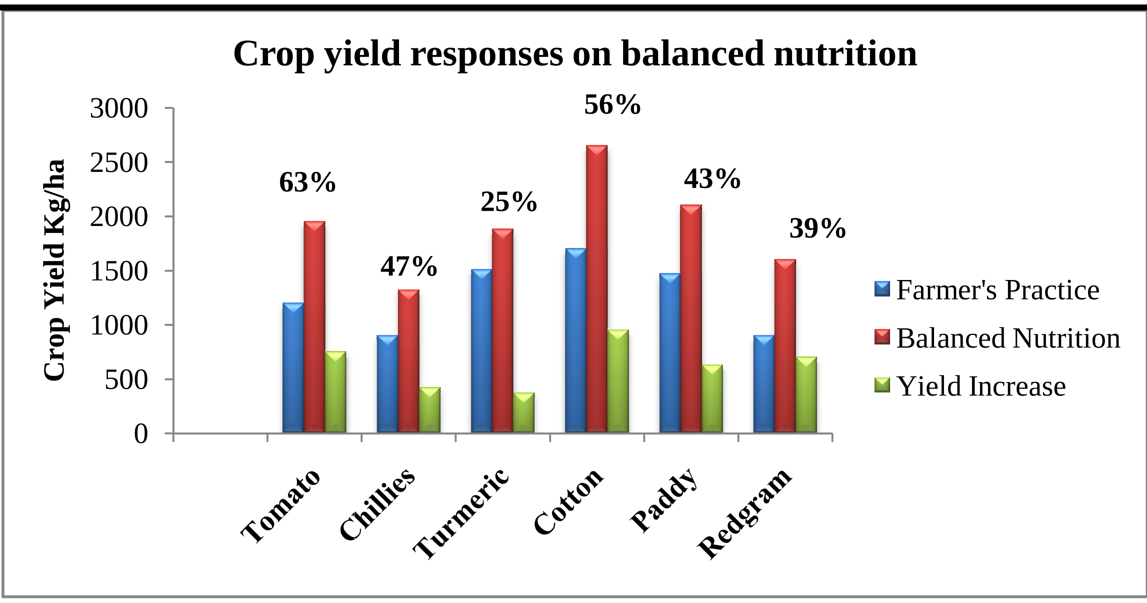

Fig.11: Graph showing significant yield responses of crops on balanced nutrition treatment over farmer's practice

Different crops responded differently to balanced nutrition showing maximum crop yield increase in tomato **(63%),** cotton **(56%)**, chillies **(47%)** followed by paddy **(43%)**, redgram **(39%)** and minimum with turmeric **(25%)**.

IV. CONCLUSIONS

Considering the results of analysis of all soil samples in Nagulapally-Konapur Watershed also, maximum deficiency was observed with Available Phosphorous (95% of total farmers field were deficient), followed by Available sulphur (84% deficiency), from 110 farmer's field, about 53% of soil samples were found deficient with Available Boron and the least deficiency of 42% soil samples out of 110 farmer's field was observed with Available Zn. K and Na were found to be adequate in all the soil samples. Moreover, the application GIS techniques to democrate the locational distribution of the estimated fertility parameters of soil through spatial distribution maps proves to be an efficient tool to identify the deficient farmer's fields. Thus, GIS techniques can be used as an easy, simple and quick tool to identify the deficient farmer's fields with good accuracy. The results showed remarkable impressive yield responses to balanced nutrient management (FP + application of S, B and Zn micronutrients) as compared to farmer's practice treatment (application of N, P and K) and different responses were recorded with different crops. Thus, the results show that for sustained increase in productivity, the rain fed crops need application of Zn, B and S along with N, P and K.

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