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A Brief Description of Spatial Analysis and Superimposing of Essential Elements in Pomegranate Using GIS Technique

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Spatial variability of soil properties and accompanying variability in plant nutrient concentration in a pomegranate growing enterprise was mapped using GIS technique. About 23 acre land in a farmer's field was selected and intensively sampled on a regular grid spacing of 21 m. Geo-statistical analysis was used to describe the spatial variability. The geo-statistical procedure of Kriging was used for interpolation of grid data to understand spatial correlation between neighbouring observations and to prepare contour maps. Among the essential elements studied, the available Mg in soil showed a good relationship with plant Mg, while for all other elements, the relationship between soil and plant nutrients was very poor. The variogram models of soil properties indicated that most of the properties exhibited definable spatial structures. pH, available N, Ca, Mg, Fe, Mn and Zn showed strong spatial dependence, whereas available P, K and S showed moderate spatial dependence. Most of the plant nutrients exhibited high nugget : sill ratio indicating often mismatch between soil available nutrient and plant nutrient concentration. The extent to which the spatial variability of soil available nutrient mimicked that of plant nutrient status was a function of nutrient element in question. Application of GIS for nutrient mapping was found useful for developing nutrient management strategies in pomegranate.

Key words: GIS technique, spatial analysis, soil and plant nutrient status, pomegranate

The nutrient requirement for perennial fruit crops like pomegranate (*Punica granatum*) through soil testing is done by comparing the soil available nutrient status with established ranges for soil under question. Alternately, the mineral composition in selected plant samples in pomegranate leaf provides insight on nutrient requirement. Conventionally, one or a few samples are collected within the field for assessment of nutrient requirement. However, when soil sampling approach is adopted, the spatial variability in soil properties poses problem for sampling and diagnosis of nutrient requirement. When plant sampling approach is adopted the nutrient interactions within the plant vitiates the diagnosis of nutrient imbalance (Fageria 2001). To overcome this problem, grid sampling has been widely used for understanding spatial and temporal variations as it provides excellent information about intrinsic and management induced variations within the field (Balasundram *et al.* 2008). Grid sampling helps in GIS application which envisages application of geo-statistics to describe the spatial variability. The basic objective is to generate information on unknown locations/points which is not sampled when limited samples are collected within a field. The geo-statistical procedure of Kriging is applied for interpolation of grid data to understand spatial correlation between neighboring observations and to prepare smooth contour maps. The spatial dependence between two neighboring samples is explained by semi-variance. As the distance between the two samples increases as the variance increases (Kirandeep *et al*. 2011).

Pomegranate is an important fruit crop in India and nutrient management is one of the most challenging production constraints. Notwithstanding, many progressive farmers are making use of soil and plant analysis facilities for improving yield potential. The present investigation was taken up to find the spatial variability in a pomegranate growing enterprise and to establish relationship between soil available nutrients and plant nutrient status by preparing

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nutrient contour maps. This article shows how diverse soil properties can be integrated to make soil and plant analysis more meaningful for fertilizer recommendation by making use of data generated locally in a pomegranate orchard.

Material and Methods

Grid sampling

Twenty three acres of land in a farmer's field in Ballalasamudra of Hosadurga was demarcated and intensively sampled on a regular grid spacing of 21 m. The four geo-coordinates of the farm were roughly identified using global positioning system (GPS) operator. Surface soil samples (0-15 cm) were collected from 140 grid points. Soil samples were analyzed for different nutrients in order to develop nutrient contour maps. A composite leaf sample from four to six plants surrounding each grid point was collected. The 8^{th} pair of leaf from the top was collected (Anonymous 2004). The relief within the study plot was less than 1 m.

Analysis of samples

Soil samples were analyzed for pH, electrical conductivity (EC), organic carbon (OC), available N, P, K, Ca, Mg, S, Fe, Mn and Zn by following standard procedures (Page *et al*. 1982). The plant samples were analyzed for N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu as outlined by Jones *et al*. (1991). The foliar samples were dried at 65 °C, wet digested with H_2SO_4 and H_2O_2 and analyzed for N by Kjeldahl method. Another part of the sample was digested with HNO_3: $HClO_4$ (9: 4, v/v) and P was estimated by vanadomolybdate method and S by turbidimetric method. Atomic absorption spectrophotometer was used for determining Ca, Mg, Fe, Mn, Zn and Cu. Potassium was estimated using flame photometer.

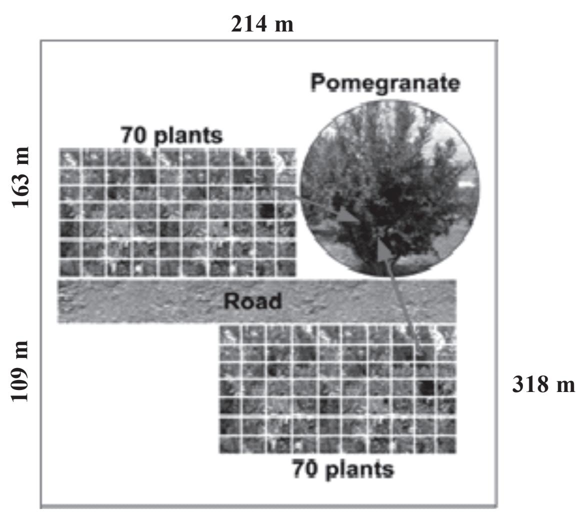


Fig. 1. Grid sampling in pomegranate

Geo-statistics

Geo-statistical analysis was used to describe the spatial variability. Sampling grids were digitized as polygons using GIS software. The geo-statistical procedure of Kriging was used for interpolation of grid data to understand spatial correlation between neighboring observations and to prepare contour maps.

The results of the soil and plant analysis were used in descriptive statistical analysis by calculating mean, median, minimum and maximum values, skewness and kurtosis. The spatial dependence was analyzed by semi-variogram based on the accepted stationarity assumptions which constitute intrinsic hypothesis of regional variable theory (Webster 1985). The geo-statistical parameters were derived by placing grid values in XY coordinates.

$$S^2 = 1/2M\sum_{i=1}^{m}[Z(X_i) - Z(X_i + h)]^2$$

where, S^2 is the semi-variance for 'm' pairs of observations and $Z(x_i)$ and $Z(x_i + h)$ are observations separated by the distance 'h' usually known as lag. The coefficients of the semi-variogram theoretical model *viz*., nugget effect, range sill were estimated. The degree of spatial dependence of the properties under study was interpreted by the classification of Cambardella *et al*. (1994), which considers strong spatial dependence of semi-variogram with nugget: sill ratio <25% , moderate when the ratio is between 25 and 75% and poor when the ratio is >75%.

Results and Discussion

Soil properties

Soil reaction varied form near neutral to acidic, while for most of the samples EC was in the safe range. Organic carbon content was moderate and N was marginally low. Both P and K were in optimum range in most of the samples. The DTPA extractable Fe, Mn and Cu were in optimum range when compared to the established ranges, whereas mean Zn was marginally low in few samples (Table 1). Such large variations in soil properties within a small area is not uncommon and other studies evaluating spatial variations found similar variation in soil properties within a localized area (Kirandeep *et al*. 2011).

Table 1. Soil available nutrients in pomegranate orchards under grid sampling

	Mean	Min	Max
pH	5.42	4.16	7.76
EC (dS m^{-1})	0.28	0.10	0.83
OC (%)	0.51	0.20	1.72
N (ppm)	82.6	32.1	278
P (ppm)	8.39	2.14	33.9
K (ppm)	184	77.5	350
Ca (ppm)	2548	709	5357
Mg (ppm)	214	56.5	363
S (ppm)	53.1	10	165
Fe (ppm)	15.7	7.98	33
Mn (ppm)	28.6	6.75	68.2
Zn (ppm)	1.21	0.48	18.4
Cu (ppm)	1.88	0.83	5.90

Plant nutrient status

The mean N, P and K concentration in pomegranate leaf sample were 2.43, 0.26 and 1.48%, respectively. Phosphorus concentration in leaf was not yield limiting factor and in many cases, had marginally higher P in leaf and nearly all most all the samples had P greater than established critical value of 0.18% (Anonymous 2004). All the samples were in optimum range with reference to K when compared to the established standard (>0.61%). Calcium concentration showed wide range and was generally high ranging from 0.59 to 4.83%, while Mg concentration was in optimum range in majority of samples compared to norms developed elsewhere. Iron concentration was higher than the optimum range developed earlier and it varied widely from 85 to 355 ppm (Table 2). Both Zn and Cu concentration was in general on the higher range. Boron concentration showed wide variation in leaf ranging from 5.3 to 30.5 ppm.

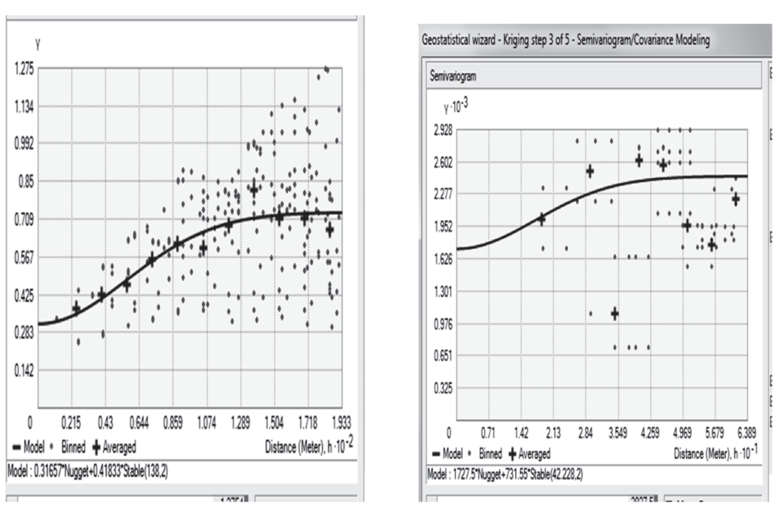
Table 2. Nutrient concentration in grid-sampled pomegranate leaf samples

	Mean	Min	Max
N (%)	2.43	0.32	3.93
P (%)	0.26	0.01	0.60
K (%)	1.48	0.90	3.60
Ca (%)	2.26	0.59	4.83
Mg (%)	0.65	0.36	1.08
S (%)	0.29	0.16	0.49
Fe (ppm)	208	85.5	355
Mn (ppm)	110	33.6	277
Zn (ppm)	39.2	13.4	175
Cu (ppm)	26.2	10.8	58.1

Nutrient contour maps

Although array of soil and plant nutrients were mapped, only the N distribution in soil and plant system is illustrated for sake brevity. Application of variogram models indicated that most of the properties exhibited definable spatial structure although the models they subscribed to were different for each element and were either linear with sill, exponential or Gaussian. Among different soil parameters some were spatially dependent and some were spatially independent.

Nitrogen distribution followed stable model both in soil and plant (Fig 2). The distribution of available N in soil was patchy and there was region of high N



(a) (b)

Distance (x axis) *vs* Semi-variance (y axis)

Fig. 2. Schematic representation of nitrogen semi-variogram model for soil (a) and plant (b)

Table 3. Assessment of the status of soil and plant nutrients in pomegranate orchard and geo-statistical summary

Variant	Soil	Plant	Nugget (Plant)	Sill (Plant)	Superimposing
N	Optimum	High	0.316	0.418	No Agreement
P	Optimum	High	0.0053	0.023	Poor Agreement
K	Optimum	Optimum	0.087	0.024	No agreement
Ca	High	High	0.28	0.08	Partial agreement
Mg	Optimum	Optimum	0.009	0.002	Good agreement
S	High	Optimum	0.002	0.004	Poor agreement
Fe	Optimum	Optimum	1805	651	Poor agreement
Mn	Optimum	Optimum	0.001	1396	Poor agreement
Zn	Optimum	Optimum	514	74	Poor agreement
Cu	optimum	Optimum	30.75	49.09	Poor agreement

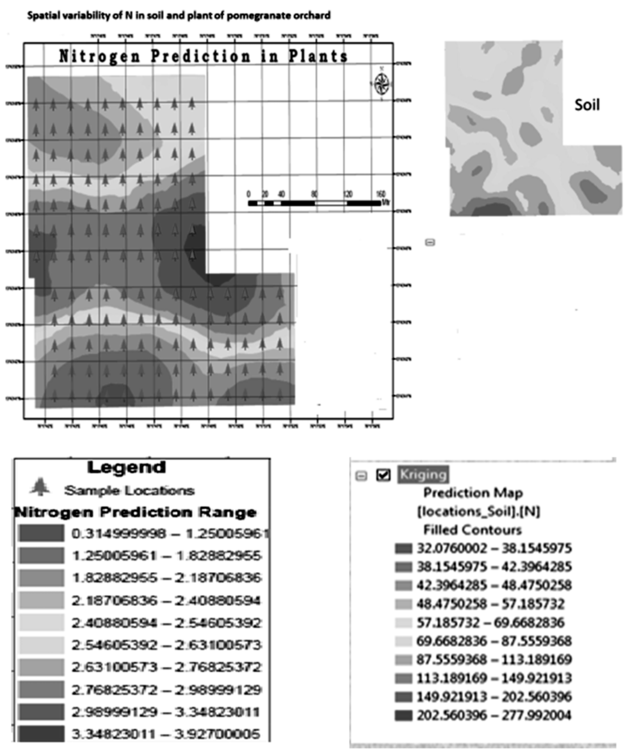


Fig. 3. Nitrogen contour maps for plant and soil

on one side of the farm and plants growing nearby did not show similar high N in leaf samples. The nugget:sill ratio for soil was (236.3%) and was higher when compared to nugget:sill for plant (75.6%) indicating that N levels in plant showed much higher spatial dependence compared to soil N. Nitrogen concentration in plant showed a poor relationship with available N in soil. This is primarily because of poor microbial activity of arid region soil and therefore low uptake by plant. Figure 3 indicates several vital facts regarding N management in pomegranate taken as an example. There was a patch of land where N was very low in soil and therefore higher level of N application is required than the recommended value. However, it is to be observed that the N levels in soil was not reflected in plant as one can make out visually superimposing soil and plant contour maps. Literature is replete with information on poor relationship between soil available N and leaf N concentration in pomegranate (Raghupathi *et al*. 2002) notwithstanding adequate N in soil.

The K concentration variation in soil and plant also showed poor correlation and often were not related. In general, the K concentration in soil was higher while majority of the area in plant showed a very low K content. Phosphorus distribution within the orchard showed far greater spatial dependence (nugget: sill ratio 23.0), whereas K exhibited very poor spatial dependence. Similarly, some of the micronutrients like Fe and Zn also showed poor spatial dependence.

Among the 10 nutrient elements studied, element by element comparison indicated that only Mg showed very good agreement between soil and plant status. The nugget: sill ratio value for a given element was more often lower for plant compared to the ratio for soil indicating that plant nutrient was spatially more dependable when compared to soil available nutrient levels. None of the micronutrients showed agreement between soil and plant status with reference to spatial variability. This was partly because of poor mobility of micronutrients within plant and also due to existence of interaction within plant with other nutrients (Fageria 2001).

Conclusions

Spatial analysis through GIS application was instrumental in establishing relationship between available nutrients in soil and its concentration in plant in pomegranate. Understanding nutrient behaviour in soil and plant is important as illustrated above. However, the GIS application can be extended to soil physical, chemical and even to biological properties and integrate them effectively. The optimum ranges have been developed for pomegranate both soil parameter and plant nutrient status earlier, however often the interpretation based on such comparison was too vague. Nutrient application has been taken up based on annual demand of the crops rather than spatial demand. The study indicated that understanding the spatial variability across the same study site provided means estimating nutrient requirement from management perspective.

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