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Use of statistical and spatial analysis for investigating variations in an onion field at El-Saff, Giza, Egypt

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A b s t r a c t. The main objective of this study was to determine spatial variability in a dry onion field in EL-Saff agricultural farming village, Giza Governorate, and to produce a management strategy which is based on spatial variability of yield and soil components. The onion field properties were determined and given in maps. Soil samples were taken to determine properties of soil such as salt (EC), pH, available N-P-K, and onion yield. Longitudinal slope was also measured. Results were used to produce maps. The greatest percentage of the field soils was determined as sand to sandy loam textured soils and loamy sand in lower depth. Their surface is covered with a lot of fine and medium gravel. Yield of dry onion increased with decreasing level of total soluble salts. Available nitrogen, phosphorus and potassium in the field reflected good nutrient power supply of the studied soil as well as onion dry bulbs according to the related maps.

K e y w o r d s: precision farming, spatial variability, yield map, onion

INTRODUCTION

Growing of dry onion by sets is considered in 3 steps; seed growing, onion set growing and dry onion growing (Ulger *et al.,* 1993). The parameters for planting of sets were of a grid with 25 x 25 m row spacing, 20-40 cm planting depth of sets, and planting density of 25-45 pieces m^{-2}. Planting was done by hand, into rows opened by cultivator or harrow, in February and March for dry onion growing. The sets were covered by harrow in the conventional method. Plants were hoed 2-3 times by hand in May and June. Onions were dug by hand in August and dried approximately 7-10 days in the field.

The first step is production of dry onion by onion sets, and the second by seeds, used only for irrigated areas. There are some problems, such as planting of onion seeds for the production of onion sets. The planting of seed is realized by human labour, because row spaces between seeds are very narrow (3 cm). There are two methods for dry onion production. One of them is production of dry onion from seeds, and the other method is production of dry onion from onion sets, which is the most widely used method in Giza Governorate, Egypt (Ulger *et al.,* 1993).

Yield maps are important tools for producers or scientists practicing site-specific management in precision agriculture programs. Detailed yield maps can be linked by global positioning systems (GPS) coordinates to other maps that show soil chemical and physical properties, soil depth and topography, remote sensing data, weeds, diseases, nematodes, insects, and cultural practices (Schubert *et al*., 2002).

There are a number of ways to measure crop yields. Most methods developed over the years have involved weighing the crop after it has been separated and cleaned. Three major yield measurement approaches are listed below. Yield monitoring has been most widely applied to grain harvesting, but is certainly not limited to grains. Yield monitors are being or have been developed for several non-grain crops, such as potatoes, tomatoes, sugar beet, peanuts, cotton and forage crops (Morgan and Ess, 1997).

Yield mapping and soil sampling tend to be the first stage in implementing water retention curve. Yields are reduced by processing data from an adapted combine that has a vehicle positioning system integrated with a yield recording system. The combine has a transmitter-data recorder fitted to it that can be identified by the GPS receiver on the roof of the cab and the differential aerial above the engine. The output from the combine is a data file that records every 1.2 s the position of the combine in longitude and latitude, with the yield at that point. This data set can then be processed by various geostatistical techniques

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(usually involving kriging) into a yield map (Blackmore, 1999b). Bahnassy *et al*. (2001) applied land suitability using MicroLEIS program in integration with SALTMOD to predict the effect of water table and salinity on the productivity of wheat in sugar beet area, west Nubaria, Egypt. They found that the productivity of wheat will decrease due to increasing salinity and water table depth, as a result of mismanagement practices.

The main objective of the study presented in this paper was to determine spatial variability in a dry onion field and to produce a management strategy, based on spatial variability of yield and soil components, to improve yield for dry onion production in El-Saff area. In this research, there was a GPS apparatus for measurement of soil properties and positioning of the data. All data were measured by using transportable weighbridge and evaluated by known software.

MATERIALS AND METHODS

Description of the study area

El-Saff is one of the Giza Governorate districts. It lies on the eastern bank of the River Nile, while all other parts of the Governorate are on the western bank. The study area is a part of El-Saff district, the most precious that exist in Arab Al-Hissar area. It is situated between latitude 29° 39’ 01" and 29°38’58" N, and longitude 31°19’26" and 31°19’29" E, occupying an area of about 2835 m^2 (Fig. 1).

Regarding the climatic conditions of the area, it is characterized by hot and rainless summer, and mild winter with low rainfall. Climatic data of EL-Saff district: mean annual temperature is 21.1ºC, average rainfall total is 3.4 mm, average evaporation per day is 6.6 mm, and average relative humidity is 58.2 % (Moussa, 1991).

The experimental materials were onion field and dry onion. The onion field properties were determined and given in maps. Dry onion variety was Yarim Imrali.

Thirty eight soil samples were taken to determine the properties of the soil, such as pH, salt, total N, P, K and longitudinal slope (ISSS-ISRIC-FAO, 1998). Longitudinal slope was measured with GPS and plotted on Map. Accuracy of the GPS NAVDLX-10 was ± 0.2%. The field was divided with a grid with dimensions of 25 x 25 m. Field markers were used to determine the grid position in the field. Each grid section was harvested by hand and dry onions were put in sacks and weighed with a weighbridge.

Based on the morphological characteristics of the examined profile and laboratory analysis of the collected soil samples, and according to the classification of soils, there are Typic Torripsamments and Typic Gypsiorthids soil subgroup in the area (Kacar, 1995; U.S. Soil Conservation Service, 2003; Moussa, 1991). There are soil texture types such as sandy (S), coarse and fine loam (CL), loamy sand (LS) and clayey (C). The majority of the soils (90%) in the region are low or very low organic matter, and 45% of the soils are rich in calcium carbonate (Moussa, 1991).

Measured results were used to produce maps (soil EC and pH component maps, yield maps, plant nutrition elements maps, *etc*.) to show the relationship between yield variability and soil properties. The maps were produced by using a methodology developed and published by Denmark Royal Veterinary and Agricultural University, Centre for Precision Farming (Blackmore and Marshall, 1996; Blackmore, 1999a; Akdemir and Blackmore, 2004; Akdemir *et al*., 2005).

Positioning of data points on the maps was determined with relation to field size. Coordinates of the onion field are illustrated clearly in the maps. Data will also be used to

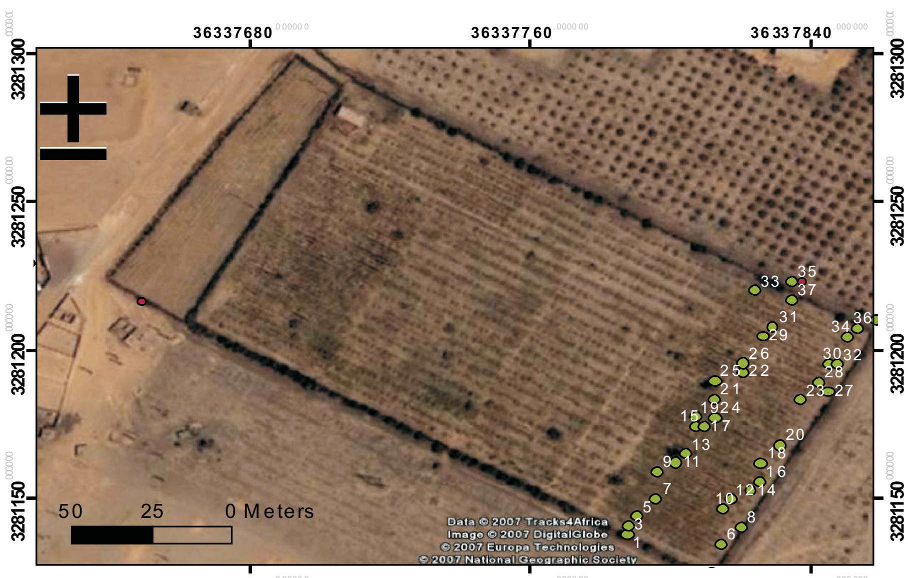

Fig. 1. Location of sample points in study area.

determine next year fertilizing strategy for different agricultural applications, such as chemical applications, seeding rate, *etc*. Produced maps will be used to investigate the reasons of yield variability in the field. In addition, the effect of soil properties and field slope on the yield will be evaluated.

Map analysis

The interpolated values of the variables were imported into ARC/INFO (ESRI Inc., 1994-2004) to create the maps. Correlation and regression analyses were conducted to measure the relationships between the mapped values of available N-P-K and those of soil variables. These relationships, among the mapped variables, may be compared with those among the data for the original 38 sites from which the maps were derived.

RESULTS AND DISCUSSIONS

Statistical characterization of data

The statistical results of the EC, pH and available N-P-K measurements for the study area are listed in Table 1. The statistical analysis can only explain the sample difference in volume and homogeneity, but it cannot describe the spatial variability. The mean of EC values before and after harvest in the 38 samples was 0.84 and 0.84 dS m^{-1}, with a large range of about 1.08 and 2.97 dS m^{-1} between the minimum and maximum values. The EC values of February and May are the only attributes with a bit large skewness and kurtosis, showing that the distributions of these characteristics were far from normal. The quite large positive skewness for EC values, especially after harvest in May, reflects asymmetry in the distribution caused largely by a number of relatively high values.

A natural logarithmic (*Ln*) transformation was applied to the data for EC values both in February and May, soil pH data, available N and P variables. Another benefit of transformation is that the distortion of semivariance and other computed statistics by extreme values is reduced (Journel and Huijbregts, 1978; Goovaerts, 1997). After transformation, the skewness and kurtosis of EC values were greatly reduced, providing a more normally distributed data. Data of available K and yield were distributed in an approximately normal fashion.

Soil pH ranged from the slightly acid 6.29 to the neutral pH of 7.24, with a mean of 6.79. Soil pH varied only about 0.95-fold between their respective minimum and maximum concentrations. The statistical distribution of available K and yield data was reasonably normal as shown by the values close to zero for skewness and kurtosis (SAS Institute Inc., 1988). Available potassium was less variable. The distributions of soil pH, P, K and yield values were only slightly skewed (skewness <1), and their medians were quite close to their means, while they were somewhat farther in the case of the nitrogen data. As mentioned before, when the content of salt in the soil samples was investigated, it varied according to its spatial position. Figures 2 and 3 show the frequency distribution of EC dS m^{-1} values in the study area in respect to the yield, before the harvest in February and after the May harvest, respectively. Both data exhibit abnormal distribution that was attributed to *Ln* transformation prior to kriging.

Semivariogram analysis

Semivariograms were prepared for the selected seven variables. The semivariances were calculated from 19 pairs of samples. The semivariograms were limited to an average separation distance of 12.9 m to avoid distortions in semivariance caused by the arbitrary restriction of site-pairs by the boundaries of the area sampled. Omnidirectional semivariograms were prepared, but it should be noted that, because of the rectangular shape of the site, these variograms are dominated by trends in the north-south direction. All of the variograms show a high degree of spatial dependency. Thus, for most variables, we were able to fit at least a portion of the experimental semivariogram with the spherical model, then exponential, Gaussian and linear model using the parameters listed in Table 2.

T a b l e 1. Statistical summary of data

Items	Mean	Median	Standard deviation	Sample variance	Min.	Max.	Sekwness	Kurtosis
EC (dSm^{-1}) February	0.841	0.78	0.242	0.059	0.63	1.71	1.85	3.29
EC (dS m^{-1}) May	0.946	0.8	0.504	0.254	0.3	3.0	2.35	6.86
pH	6.796	6.85	0.250	0.062	6.29	7.24	-0.32	-0.79
N (kg ha^{-1})	1385.681	1232.17	463.585	214911.474	773.83	2333.38	0.57	-0.90
P (kg ha^{-1})	202.260	191.67	53.677	2881.183	115.24	304.77	0.35	-0.96
K (kg ha^{-1})	963.052	933.352	315.750	99698.309	223.81	1500.03	-0.35	-0.30
Yield (t ha^{-1})	24.149	26.19	6.421	41.227	9.52	36.91	-0.29	-0.64

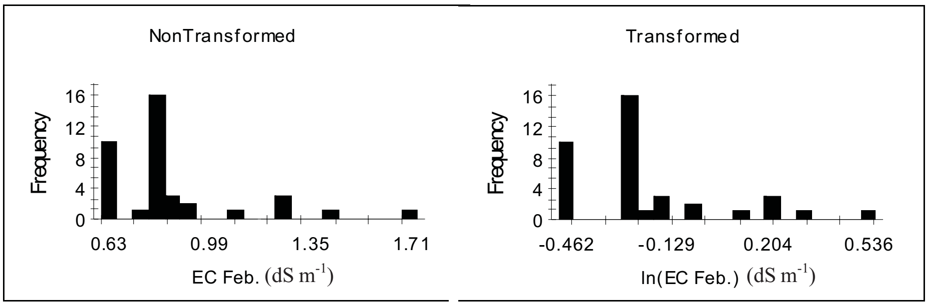

Fig. 2. Frequency distribution of EC dS m^{-1} values in February before harvest.

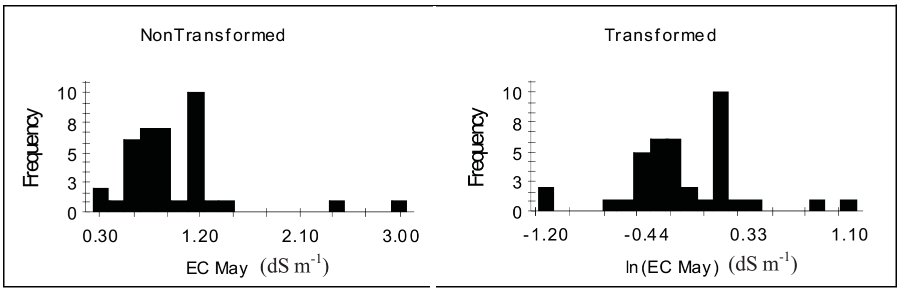

Fig. 3. Frequency distribution of EC dS m^{-1} values in May after harvest.

T a b l e 2. Parameters of the models used to describe isotropic semivariograms for the studied variables

Parameters	Variogram model	Nugget	Sill	Range	Variogram model fitting		
		C_0	$(C_0 + C)$	*A*	RSS	R^2	$C/(C_0+C)$
EC (dS m^{-1}) February	Linear	0.072	0.072	51.02	0.01	0.00	0.000
EC (dS m^{-1}) May	Exponential	0.004	0.180	0.30	0.02	0.00	0.978
pH	Gaussian	1.750	1.390	6.93	1.40	0.27	0.874
N (kg ha^{-1})	Exponential	0.011	0.107	6.00	9.25	0.04	0.893
P (kg ha^{-1})	Spherical	0.033	0.073	14.50	1.70	0.34	0.544
K (kg ha^{-1})	Spherical	100.00	85500.0	2.80	2.95	0.00	0.999
Yield (t ha^{-1})	Spherical	2.00	42.18	9.10	5.12	0.30	0.947

None of the variograms for the selected seven variables in this research were bounded by a constant sill, when the entire range of data was considered. After *Ln* transformation and removal of the trend, the residual (detrended) values were used to recalculate the semivariances. This process significantly improved the semivariograms for EC, pH and P, but the improvement for nitrogen N was only slight.

The variogram of EC dS m^{-1} February increased almost linearly with lag distance, suggesting a linear trend that was modelled showing a very small nugget variance and sill with a range of about 50 m (Fig. 4). The detrended variograms for EC dS m^{-1} May and available N were fitted by the exponential model using range distances of 0.3 and 6 m, respectively, and the nugget and structural variances given in Table 2.

Figure 4 shows the semivariogram of pH which was fairly well described throughout the range of the data by the Gaussian model. The fitted curve for relative semivariance has a small nugget variance, a large structural variance, and a range of 6.7 m (Table 2). In the case of phosphorus, potassium and yield attributes, no corrections for periodicity were used in modelling the semivariogram for them, because the simple spherical model provided a reasonable fit, especially at short-range lag distances which dominated the interpolation process based on the 19 closest points (Fig. 4).

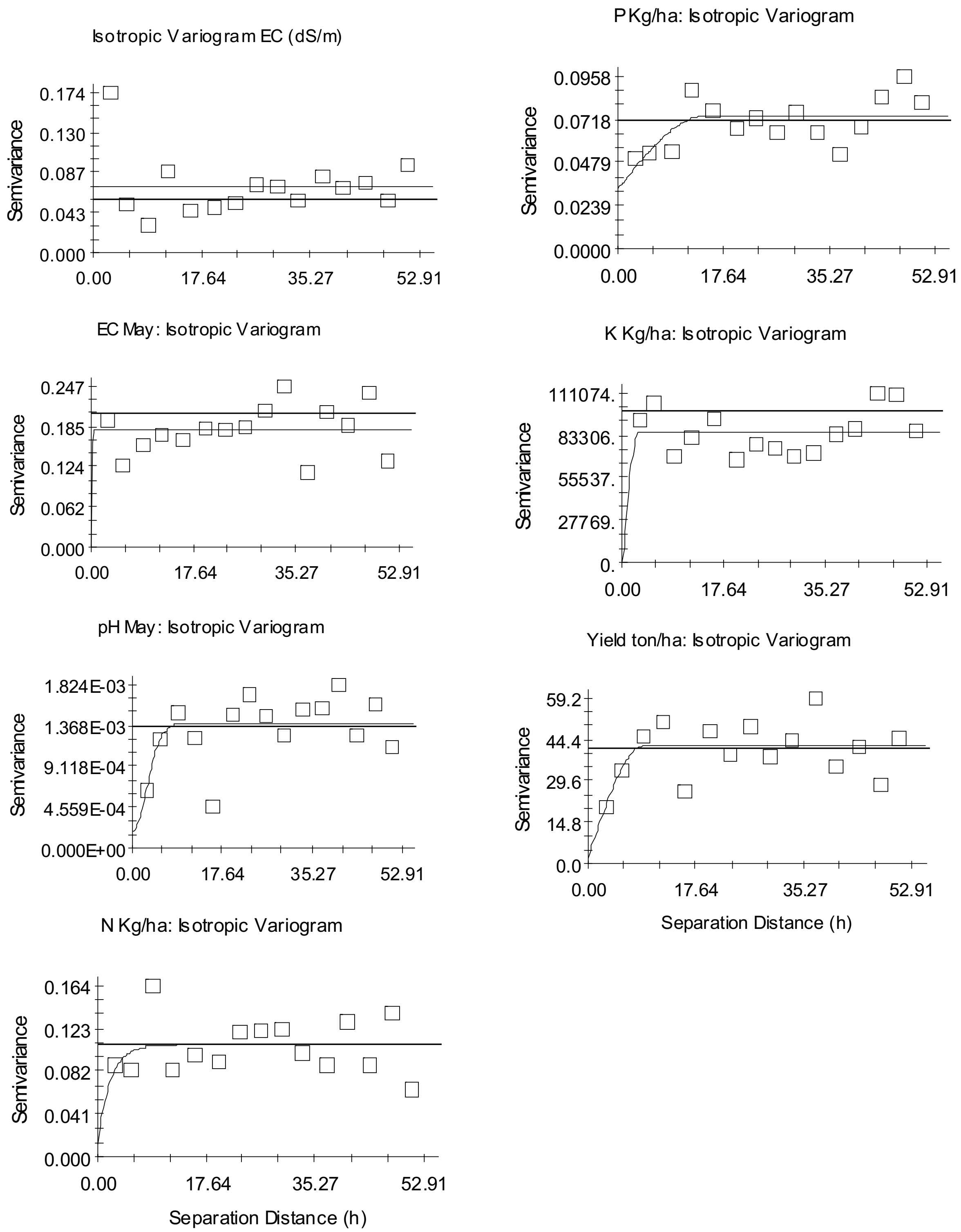

Fig. 4 . Semivariograms of EC (February and May), soil pH, available N-P-K and crop yield characteristics.

In general, the obvious positive small nugget, the proportion of sample variance $C/(C_0+C)$ and the relatively small RSS values indicate better fitting of variogram models and significant structural of spatial variability.

Map preparation and comparison

The produced maps are given below. Variability of the soil, yield, pH, available N-P-K and others can be seen on these maps. The maps can be used to determine spatial variability and to apply variable rate application in that field.

The distributions of soil characteristics, available N-P-K and crop yield in the field are most easily seen when portrayed in maps. Using the fitted parameters of nugget, sill, and range (C_0, C, and A), the outcome of semivariogram analysis, the block kriging was performed with a block size of 2 by 2 m^2 to obtain interpolated values for all selected variables across the sampled area of 2835 m^2 *ie* 105 by 27 m^2. For soil EC, pH, N, P, K and yield, the kriging interpolation method was performed on detrended data, after which the trend surfaces were added to their kriged values to yield the final interpolated values. The produced maps based on the final interpolated values were prepared with ARC/INFO (ESRI Inc., 1994-2004).

After calculating the semivariogram parameters and choosing the best variogram model with its building parameters that fit with linear isotropic model, the ordinary block kriging algorithms was applied to interpolate the EC data using the GeoStat and Surfer programs. The resulting block-kriged map of EC values before and after harvest for the study area is illustrated in Figs 4 and 5. Normally, the smoothness of spatial distribution map illustrated the degree of spatial variability in soil salinity data characteristics. When evaluating the EC maps, it can be seen that there is not much variability of salinity before harvest, except in the western part of the field with higher levels. In May, after harvest, the salinity is changed between 0.3 and 3 dS m^{-1}. The salinity is generally low between 3281122 and 3281180 north coordinates. In the northern parts of the field, there is big variability for salinity and reaching higher levels.

The regression coefficient for salinity map = 0.6. The standard error of the regression coefficient SE = 0.59. The R^2 value is the proportion of variation explained by the best-fit line = 31%, and the y-intercept of the best-fit line is also provided. The SE Prediction term is defined as SD x $(1 - r^2)^{0.5}$, where SD = standard deviation of the actual data (SE = 51).

On the other hand, the map for soil pH does not resemble that for any other characteristic. The pH of the research field varied between 6.29 and 7.24 (Fig. 6), whereas onions are grown best on slightly acid-neutral soils (Allen and Timbrell, 1987), which fitted well with the spatial variability range provided (pH 6.68 to 6.91) in most of the study area. Expected satisfactory yield can be obtained in most cases.

The amount of available nitrogen taken from the soil by the determined amount of dry onion varied between 773.83 and 2333.38 kg ha^{-1}. Figure 7 shows clearly that the spatial characteristics of nitrogen were not distributed in a random manner across the field. The nitrogen variable showed a pronounced tendency for local clustering of similar values, with gradual changes from areas of low to high values from south to north direction of the sampled area. Samples collected from the soil at the southern part were generally low in available N, while samples from the north were typically higher.

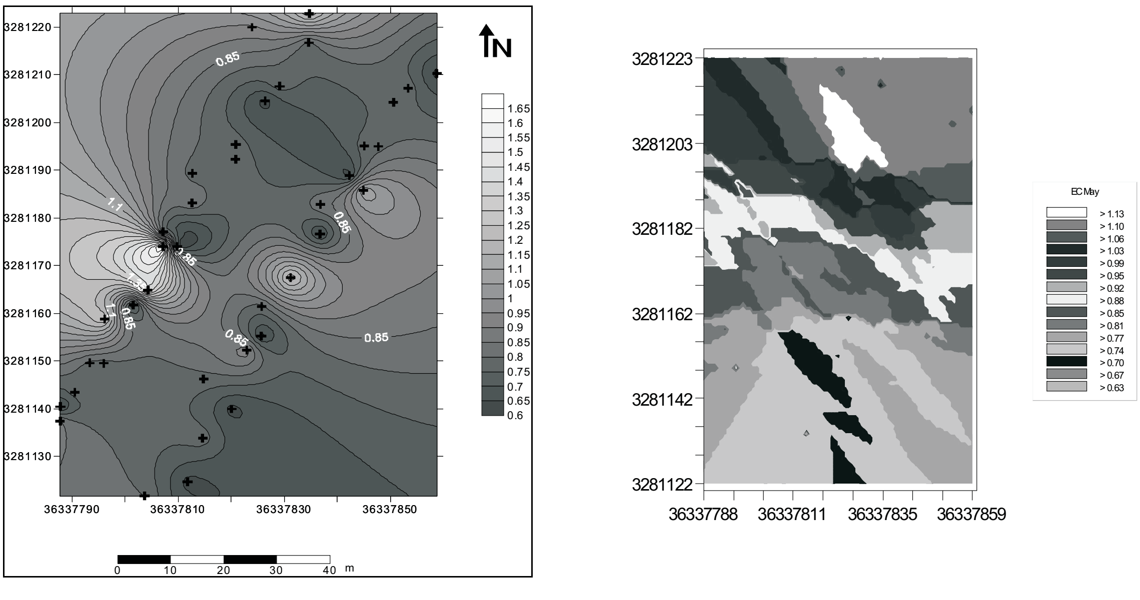

Fig. 5. Maps of EC (dS m^{-1}) measurements before (left) and after (right) yield harvest.

The distributions of available P and K are reasonable, but they are unlike each other and also differ from those for other characteristics, except for the obvious similarity between K and EC after harvest maps (Figs 8 and 9). Maps for available K and EC dS m^{-1} of May were similar, showing visually the association of K with the salinity-related characteristics, especially after yield harvest. The distribution of P is gradually increasing in the NE to SW direction, but the correspondence is clearly less close in relation to salinity. Available phosphorus deficiency causes slow growth, delayed maturity, light green foliage, and high proportion of thick necks (Allen and Timbrell, 1987).

When evaluating the yield map, it can be seen that there is variability for yield in the field (Fig. 10). The yield is changed between 9.52 and 36.91 t ha^{-1}.

The yield is generally moderate, at 23 to 24 and up to 26 t ha^{-1} in most parts of the study area. In the other parts of the field, there is big variability for yield. Yield distribution showed a pronounced tendency for local clustering of similar values, with gradual changes from areas of low to high values.

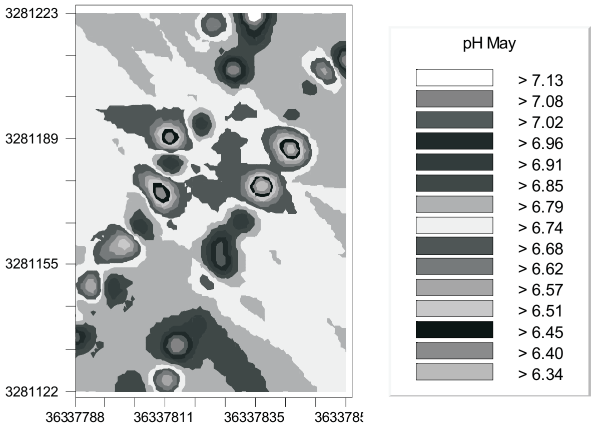

Fig. 6. Soil pH map.

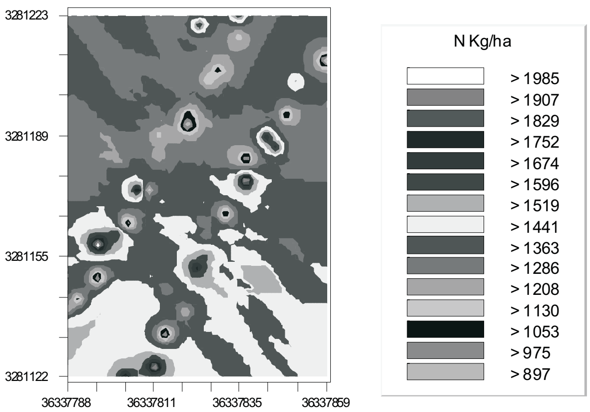

Fig. 7. Map of available nitrogen (kg ha^{-1}).

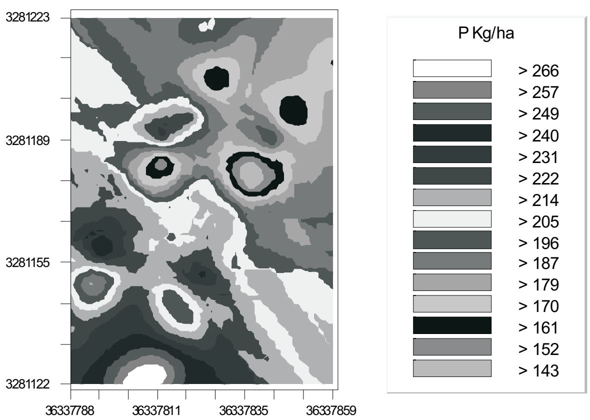

Fig. 8. Map of available phosphorus (kg ha^{-1}).

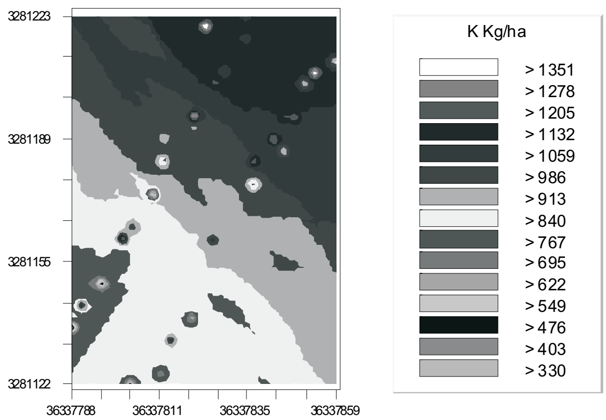

Fig. 9. Map of available potassium (kg ha^{-1}).

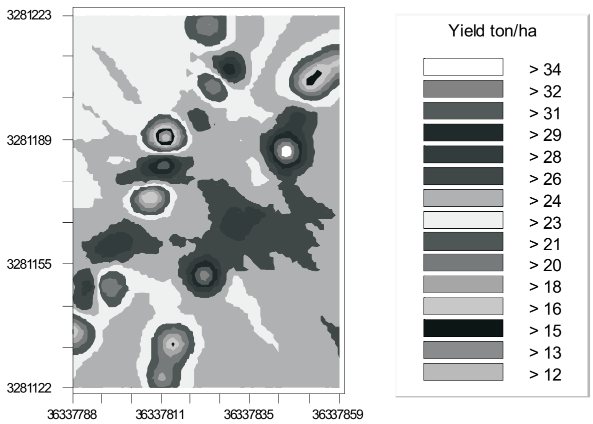

Fig. 10. Map of dry onion yield (t ha^{-1}).

When investigating the pH and yield map, it was determined that there was a lesser relationship between yield and pH in this research field. Yield of dry onion decreased with increasing level of soluble salts in the field according to the related maps. The results were measured after harvesting dry onions.

Fertilizers with N, P and K should be applied with required technical solutions protecting against accumulation and leaching of nitrogen and phosphorous. Accumulation and leaching of nitrogen and phosphorous in the soil may be prevented by using right and stable fertilizer applications. If fertilization is applied according to the soil-plant analyses, over-fertilization can be prevented. Application of fertilizers at desired amounts is becoming important for the right utilisation of source, profitability, for controlling environmental pollution, and for health reasons.

Egypt has a big potential for the application of precision agriculture but it requires time to solve problems such as education of farmers and implementation of pilot precision farming projects. If it is realized, chemical use in the agriculture will be reduced and yield of agricultural products will be increased. Precision farming applications generally require high technology but there are some opportunities, such as creating yield maps for crop production, that may be applied in Egypt. Egypt has different mechanization levels for different products. Soil tillage, pesticide application, fertilization, planting are being done by agricultural machines. Some processes of products such as economic crops, vegetables and fruit harvesting *etc*. have been performed by hand. In those fields precision farming applications can be used. Farmers should be educated for sustainable agriculture and they can learn what precision farming means. They can start create their specific precision farming solutions.

CONCLUSIONS

1. There is no big change for yield in correspondence to the longitudinal slope in the research field. In the greater part of the field, the slope varied between 2 and 3%. As a result of this negligible variation of the slope, there was no effect on the yield.

2. The highest percentage of the field soils was determined as sand to sandy loam textured soils. A small part of the field was loamy sand at lower depths. There is no big difference in the research field in respect of soil texture.

3. There is no effect of the soil texture on the yield. The determined soil textures were suitable for onion production in this research.

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