Breeding cherry tomato types for organic farming using geostatistical tools

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ABSTRACT

The conventional breeding process is based upon growing different cultivars in research fields with similar characteristics (soil, water, climate, etc.). Thus, the selected types are well suited only to fields with similar characteristics as their breeding ancestors. In contrast, in heterogeneous fields, as the organic ones, the above mentioned cultivars will suffer from inconsistency in yield. Here we demonstrate new methodology for adjusting crop cultivation to the organic practice. The study was conducted between 2001 and 2002 on cherry tomato organic greenhouse in Netzer Hazanimoshav, Northern Negev, Israel. We have chosen Nitrate as a representing parameter for the soil variability and geostatistically analyzed its suitability for spatial analysis. Afterwards, five types of cherry tomatoes were planted in the area and their growth with yield patterns were measured. Comparisons between the plants' parameters and the Nitrate variability indicated their suitability for organic growth. We are confident that using the principles of the described breeding technique will encourage farmers to grow organic crops for our own health benefits and the sustainability of the environment.

Keywords: Cherry tomatoes, Geostatistical tools, Organic culture' breeding

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INTRODUCTION

Companies and international associations invest billions of dollars in isolating crop types with high marketing value (bigger yield, better quality, resistance against pests, etc.). These types are adjusted to the cultivation 'programming'. For example, cultivars bred and selected forcertain levels of salinity will act differently if salinity is modified (even in case of a small change). In turn, deviation from the expected yield could turn the profits into loss. The conventional breeding process is based on 'Random blocks' method in which different crop cultivars are been planted in research fields with similar characteristics (soil, water, climate, pest management, etc.). Afterwards, randomly sampled plants are taken and yield parameters are measured per each cultivar. The oneswith the highest average values are chosen for further breeding processes and so on for at least several generations until a cultivar with the desired characteristics is generated (Sleper and Poehlman, 2006).

This methodology is suited only to the already tested terms and cannot indicate the suitability for other growth conditions. This is extremely relevant and critical in the case of organic farming, in which the used fertilizers are characterized by high heterogeneity in the number and amounts of nutrients due to their excrement sources (from flora and animal sources). The organic dissimilation rates are also slow and inconsistent, which also causes irregularities in soil concentrations of nutrients (Herencia *et al*., 2007). In this paper, in order to overcome the above mentioned challenges, we will introduce new technology of breeding crops for organic practice green houses. This technology was tested on sub-species of cherry tomatoes in MoshavKatif, Northern Negev and is based on spatial analysis. The technique can be implemented in commercial fields and for several parameters (could be sampled from different locations)**.**

MATERIALS AND METHODOLOGY

The research took place in Moshav (cooperative Israeli settlement) Netzer Hazzani, located in the Northern Negev (Longitude- 15^{o}34', Latitude- 20^{o}31'). The soil is defined as Sandy with deep and uniform pattern (USDA, 1999). Climate is Coastal Mediterranean with high moisture rates (66.2%-81.7%). Average annual precipitation amounts are between 300 and 400mm per season (Israel Meteorological Services, IMS). Irrigation water came from local wells.The green house was organically managed based on USDA protocols.

The green house was North-South oriented (planting order had East-South orientation) and covered with polyethylene. Its dimensions were 57X32m (0.18 ha) of which 0.165ha was planted (Fig. 1A). From that, the analyzed area was 900m^2. The plants were cherry tomatoes types '30', '31', '32', '33', '35' and '36' bred by Zeraaim Gadera co. The seeds were sprouted, grown separately on organic bed for three weeks and planted in the greenhouses at 16.08.2001. From each type, between four to five plants were randomly chosen and marked by red ribbon for further testing of parameters. Pollination was done by the Bombus bee (*Bombusterrestris*) from BioBee, SdeEliyau. Sulfur was sprayed against pests in the growing season (Jones and Howells, 2001). In the beginning of 2001, the soil was mixed with 2.5 tonha^{-1} of compost (Gaskell and Smith, 2007). The compost came from plant excrements and animal manures and was not uniform in its content. Average nutrient concentration from dry matter was as follows: N- 5.53%, C-13.197%, H-6.24%, S-2.06%, C/N=1:3, Elemental Analyzer EA1108 (Eager, 2001). Note, the name of the companies do not imply authors preferences.

Along the growth season 150 gr of Guano was added to each plant (Gaskell and Smith, 2007) and two litters of liquid urea (called also 'Cow urine') was added at planting and along the growth season (Silva, *et al*., 1999). The plants were arranged in 'Planting units'. Each 'Planting unit' was composed of two couples of four planting lines. Inside each couple the distance between the planting lines was 0.5m, and between the couples 1.5m. The distance between the plants in each line was 40cm, and the total density of the plants was three plants per m^2. Each plant was trellised over with iron wire (height of 2m) and irrigated directly with two drippers, one between four plants (1L hour^{-1}, three hours day^{-1}, total average of 2.25 L plant^{-1} day^{-1}). The nutrient chosen for analysis was Nitrate due to its dramatic effects on the cherry tomato growth and yield (Kafkafi, 2005).

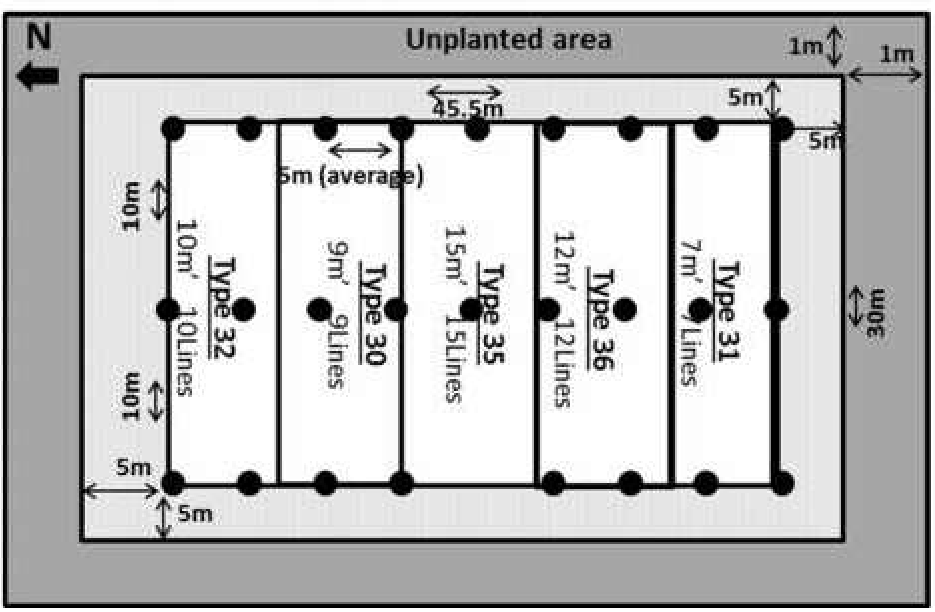

Figure 1: The organic greenhouse samplings plots and types of planting units

- Black point represents sampling point
- Solid gray represents unplanted area
- Dotted gray represents planted area
- White area represents the analyzed plot.
- The small units inside represent the cherry tomato types' units, the number of planting lines and their widths
- Arrows represent distances between samples, between the sample and plot edges, or between the plot and greenhouse edges.

Twenty six (26) samples were taken along the analyzed area (in three lines shape with distance of 10m between them and average distance of 5m between the samples on the lines). Note, the accurate locations of the plots were determined based on several factors such as distance from the plants, distance from the drippers and ease of digging.

The soil sampling was implemented at 01.03.2001. The samples were taken from depth of 0-20cm (Root zone), dried and mixed with distilled water (70ml water per 100gr of soil) for 24 hours. Afterwards, the soil solutions were drained and analyzed using elemental analyzer (Eager, 2001).
Note, due to research limitations the samples were taken half a year before the study was carried out, still newer measurements did not reveal changes in Nitrate concentrations.

Two parameters were chosen for the plant response to the Nitrate- the accumulated yield and shoot elongation.The measuring of the accumulated yield was carried out by fruit picking. The fruits were picked twice a week between 10.11.2001 and 15.2.2002 once the tomatoes reached minimal red cover of 50% and weighted. Shoot elongation was carried out between the 3.11.2001 and 6.11.2011. Measurements were done from the ground till the highest plant top (Schwarz and Klaring, 2002).

The core aim of the cherry tomato organic breeding is isolation of high yield types under conditions of high variability in nutrients (as noted, for the case study, the Nitrate was chosen for further analysis). For this propose, we, firstly, defined the spatial variability.The calculations were done using GS+ ver 5.3, Gamma Design, 2013, in five steps, part of them are related to the whole area and the other to the cultivars isolations.

a. The nutrient (In the presented study, the Nitrate) values together with their spatial locations were entered.
b. The nutrient semi-variances between the sampled plots for the whole area were calculated per each distance and divided into seven[1] groups of separation distances (Fig 1B, Gamma Design, 2013).
c. A spatial model was fitted to the data (Garrigues *et al*., 2006), and the 'Range' (the distance in which there was reciprocal effect between plots), and 'Sill' (the maximal variability in the 'Range' factor) were determined.
d. This step was aimed for evaluating the eligibility of the tested parameter for the geostatistical analysis based on the number of the taken samples and their localization.

   A kriging analysis was done on the whole area for predicting the total nitrate values (Gamma design, 2013). Note, for the demonstration we used Uniform grid and Block kriging
e. Based on the Kriging analysis the values' map of the whole area has been generated. This step was aimed at placing the tested cultivars in such a manner that each type would be allocated to an area with a maximal variability of the tested factors. Note, due to the research limitation this step was not applied, but it is recommended in any further study.
f. After the nutrients' analysis of the whole area, the relative geostatistical analysis was implemented to the area occupied by each of the cherry tomato types. The variogram of each cultivar has been calculated and its 'Sill' was assessed.

g. The presence of relationship between the Nitrate spatial variability in the field and the cherry tomato parameters indicated the suitability of the analyzed cultivars to organic farming. Note, for the geostatistical analyses, we chose the 'Uniform spherical model', which is the most used one for agricultural and ecological purposes (Garrigues *et al*., 2006). Note, there are several software based on these principles. The described one does not imply authors' preference.

RESULTS AND DISCUSSION

There was a high fit of the Nitrate values from the sampled plots to the variogram model (asexpressed in the r^2 value), (Fig. 2). The high values of the 'Range' (19m) and the 'Sill' (20,000 ppm) indicated the suitability of the Nitrate found in the organic green house to the spatial analysis. In preliminary analysis, we demonstrated the unsuitability of conventional practice greenhouse to spatial analysis (data not shown).

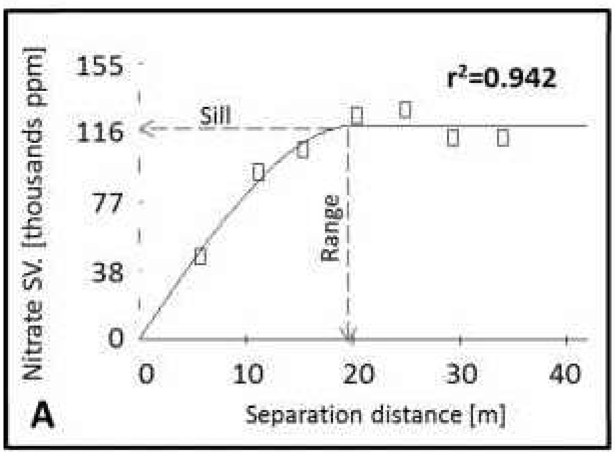

Figure 2: The variogram of the Nitrate in the organic greenhouse tested plot.

The 'Range' represents the maximal distance in which there is spatial effect.
The 'Sill' represents the maximal variability of the Nitrate in the Sill.
Note- The model is uniform and spherical with seven distance groups.

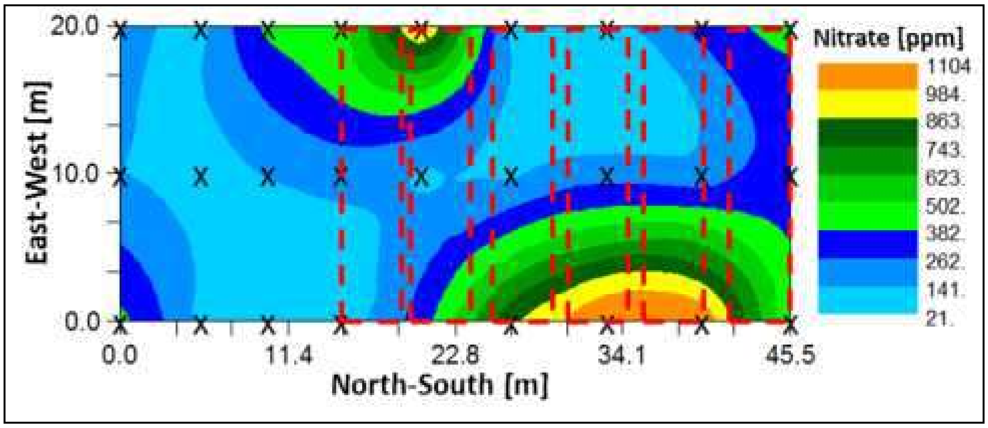

Figure 3: The Nitrate value map of the whole tested area

The 'x's represent the sampling locations
The dashed red rectangles represent the advisable locations of tested cultivars

We have also calculated the values' map of the Nitrate all over the area (Fig.3). The high variability of the Nitrate was easily demonstrable along theEast-West direction. Thus, the tomato cherry types should be planted along this gradient and grown both under Nitrate rich and Nitrate poor regimes. Afterwards we analyzed the response of the different cherry tomato types to the Nitrate spatial variability. The results are demonstrated in Fig.4.

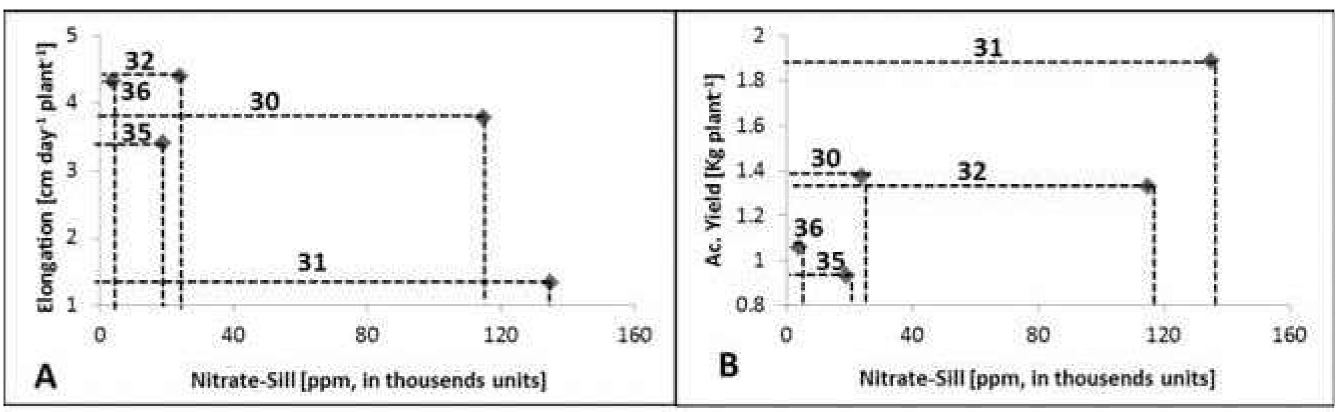

Figure 4: The relationships between the Nitarte spatial variance (The 'Sill' value) and the cherry tomatoes growth and yield parameters

A- Shoot elongation (cm day^{-1})
B- Accumulated yield (Kg Plant^{-1})

The types' analysis revealed that type '31' had the highest yield in case of the highest Nitrate variability, and the lowest stem elongation (conditions resembling maximal productivity and minimal vegetative growth). Thus, this cherry tomato type seems to be the best candidate for cultivation in the described organic greenhouse. While type '30' had higher yield than type '32', due to the fact that this yield was achieved under dramatic lower variability, one should prefer the '32' type for organic cultivation. Finally, the '35' and '36' types are the least suitable for organic practice.

This research began after conversation with local farmers on the subject of potential law suit against a breeder company due to the yield inconsistency of the cherry tomato type they supplied, when it was grown under organic conditions. Of note, the selected type had extremely high yield under conventional growth practice. This situation motivated us to develop an alternative breeding methodology aimed at the organic culture. As already described, the main advantage of our techniques is their stable and successful implementation in commercial fields for the consecutive growing seasons. Other important advantage is the ability to examine several soil parameters in parallel.While we only examined the Nitrate, additional parameters such as salinity; nutrients' concentrations could be also tested almost without any limitation by the number of samples (Vieira and Gonzalez, 2003). Additionally, the plants and the soil could be sample dat different locations, which is almost impossible to implement in case of the 'Random blocks' methodology (Johnson, 2009; Sleper and Poehlman, 2006). Altogether, the presented technique provides new directions for breeding crops on high heterogeneity fields which are ubiquitous in case of the organic farming.Nevertheless, we are fully aware of the fact that more research should be undertaken in order to reach the maximal potential of this technique**.**

Comments

[1] The 'distances groups' are one of the software factors that could be defined by the user. The authors chose the software defaults for analyzing most of the mentioned factors. Using other values requires extra study.

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REFERENCES

Eager (2001).Elemental Analyzer, Reference Manual, Eager press, US.

Gamma design (2013). GS+ GeoStatistics for the environmental sciences ver 9.0.Michigan USA.

Garrigues, S., Allard, D., Baret, F. and M. Weiss (2006). Quantifying spatial heterogeneity at the landscape scale using variogram models. Remote Sensing of Environment 103: 81–96. Available online at: http://www.creaf.uab.es/master/intranet/MaterialsProfessors/AnalisiSIG/LluisPesquer/Avaluacio/Articles/Quantifying-spatial-heterogeneity-at-the-landscape-scale-using-variogram-models_2006.pdf

Gaskell, M. and R. Smith (2007). Nitrogen Sources for Organic Vegetable Crops. Hort Technology 17(4): 431-441

Herencia, J. F., Ruiz-Porras, J.C., Melero, S., Garcia-Galavis, E., Morillo, P.A. and C. Maqueda (2007). Comparison between organic and mineral fertilization for soil fertility levels, crop macronutrient concentrations, and yield. Agriculture Journal 99: 973-983. Available online : https://www.agronomy.org/publications/aj/articles/99/4/973

Jones, G.E. and O. Howells (2001). The origin and hazard of inputs to crop protection in organic farming systems: are they sustainable? Agricultural Systems 67: 31-47.

Johnson, R.A. (2009). Statistics: Principles and Methods Fifth edition, Willey press, UK

Kafkafi, U. (2005). Effects of Ammonium to Nitrate ratio and salinity on yield and fruit quality of large and small tomato fruit hybrids. Journal of Plant Nutrition 27(10): 1795-1812.

Schwarz, D. and H.P.Klaring (2002). Growth and photosynthetic response of tomato to nutrient solution concenteration at two light levels. Journal of American Society Horticulture Science 127 (6), 984-990. Available online at: http://journal.ashspublications.org/content/127/6/984.full.pdf

Silva, R.G., Cameron, K.C., Di, H.J. and T. Hendry (1999). Alysimeter study of the impact of cow urine, dairy shed euent, and Nitrogen fertilizer on Nitrate leaching. Australian Journal of Soil Research 37(2): 357-370

Sleper, D.A.and J.M. Poehlman (2006). Breeding field crops 5th addition, Blackwell pub. Iowa.

USDA (1999). Soil taxonomy A Basic System of Soil Classification for Making and Interpreting Soil Surveys, 2nd Edition, United State Department of agriculture Natural Resources Conservation Service.

Vieira S.R. and A.P. Gonzalez (2003).Analysis of the spatial variability of crop yield and soil properties in small agriculture plots. Bragantia 62(1): 127-138. Available online: http://www.scielo.br/pdf/%0D/brag/v62n1/18509.pdf