A FIVE YEAR STUDY OF VARIABLE RATE FERTILIZATION IN CITRUS

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ABSTRACT

Citrus is a major crop in Brazil, especially in the São Paulo State, which is the main citrus production region in the world. Yet, site specific technology is still in early stages of adoption. Variable rate application of inputs is the most important tool in a Precision Agriculture system, however its effect on citrus agronomical aspects are still unknown, especially during long periods of observation. Thus, variable rate fertilizer application has been tested in citrus orchards in Brazil in a long term study. The goal is to evaluate the effects of this technology on input consumption, soil fertility and on fruit yield. Two 25.7 ha commercial orange fields were divided into variable and fixed rate fertilizer strip treatments. Data of soil electrical conductivity, elevation and soil texture were used to assess the variability of these fields. Variable rate prescriptions (lime, N, P and K) were based on soil and leaf grid sampling and yield data. Fixed rate applications followed standard prescriptions based on soil sampling and yield expectation. Results presented here are from five yield data (2008 until 2012) and four variable rate fertilizations (2008 until 2011). Field 1 showed more variability than field 2 regarding soil texture, EC and elevation. Site specific applications provided significant reduction on input consumption, mainly for nitrogen (37 and 51% less on field 1 and 2, respectively) and potassium fertilizers (41 and 18% less on field 1 and 2, respectively). In field 1, better fertility levels were found on the variable rate treatment. Along the years of evaluation, it reduced regions with excess of nutrients and enlarged areas of adequate levels of potassium and base saturation. Yield gains up to 13.1% occurred in this field. In the second field, loss on soil fertility and yield was found in the site-specific management in two years of evaluations. This field presented lower natural nutrient fertility and the variable rate prescriptions used were considered not suited for this soil condition. Overall results were better for the field with higher variability. This study showed the potential of variable rate technology to increase yield and improve soil fertility management.

Key words: variable rate technology, input consumption, long term study, Brazil

INTRODUCTION

Citrus is a major crop in Brazil, especially in the São Paulo State, which is the main citrus production region in the world (730 thousand ha – FAO, 2012). Florida, USA, is the second most relevant citrus growing region (250 thousand ha – FAO, 2012), attending mainly USA domestic market of orange juice. Most part of the Brazilian orange juice production is intended for exportation, attending mainly the European market.

Both regions face constant challenges for production. The most recent and threatening is a disease called *huanglongbing* or HLB. This disease is devastating orchards in both countries due to its high capability of spreading and no available cure. Besides phitossanitary problems, market prices fluctuation and increase on production cost (also influenced by higher demand for HLB treatment) often force growers to quite the business, since they cannot keep competitive.

Tools to increase efficiency by either reducing production cost or increasing yield is essential for citrus production. In this sense precision agriculture (PA) meet the need of growers by offering new technology that foment efficiency and sustainability. These goals are achieved through managing field spatial variability and providing accordingly amount of inputs.

PA studies devoted to citrus have begun in the late 1990's in Florida State, USA (Whitney et al, 1999). Later on, researchers have developed technology for site specific treatment, including canopy volume sensors that allow variable rate applications at single tree basis (Zaman and Schumann, 2005; Wei and Salyani, 2005; Schumann et al., 2006a). In Brazil, authors have pointed to spatial variability in landscape and on soil properties (Oliveira et al., 2009; Leão et al., 2010; Siqueira et al., 2010), which can lead to yield variability (Farias et al., 2003; Molin and Mascarin, 2007; Oliveira et al., 2009).

Although researchers have acknowledged spatial variability in citrus orchards, few studies tried to measure the benefit of site specific technology over traditional practices and its effect on the citrus crop. Zaman et al. (2005) found up to 40 % savings of nitrogen through variable fertilization using canopy size based prescription maps, but have not assessed yield or soil response after applications.

In this sense, Colaço and Molin (2012) showed the first two years of a long term experiment that aimed to compare variable rate fertilization practice against conventional treatment. The effects of variable rate technology were measured on yield, soil fertility and input consumption. This study is the first of its kind in citrus. Significant input savings was observed when using PA fertilization technique in two years of application, but long term observation is needed to attest if yield performance or soil fertility would be harmed later on.

This paper will reveal next three years of observation over this experiment. The objective of this study is to evaluate the effects of variable rate fertilization practice on yield, soil fertility, and input consumption, in a long term experiment.

MATERIALS AND METHODS

Two 25.7 ha orange groves located in São Paulo State, Brazil, were used for the experiment. Trees were planted in 2003 and 2004. The first field presents a predominant sandy clay loam soil (32% clay) and the second is on a loamy sandy soil (14% clay). The variety is Rubi on Citrumelo Swingle rootstock. Trees spacing are 6.8 m x 4.0 m in the first field and 7.5 m x 3.5 m in the second. Both orchards are non-irrigated.

To assess field variability the altitude map, soil electrical conductivity (EC) and soil texture maps were generated for both orchards.

Two treatments were implanted: variable rate (VR) and uniform rate (UR) fertilization. They were placed in intercalated pairs of tree rows (2010) (Figure 1). In the variable rate treatment, fertilization of nitrogen, phosphorus and potassium and lime applications were carried out on variable doses within the field. Applications followed prescription maps based on soil fertility, leaf nutrition and yield variability. In the uniform rate strips, fertilizer and lime applications were carried out using a single rate throughout the field, according to traditional prescription used by growers which is based on a single soil and leaf sampling and yield estimative for the field.

Variable rate fertilizations were carried using pulled type fertilizer spreader with conveyor belt and pneumatic assisted delivery mechanism, which allows fertilizer deposition under the trees canopy. Fixed rate applications were carried using a pulled type equipment with spinner disc distribution, which is the most common type of equipment used in Brazilian citrus orchards.

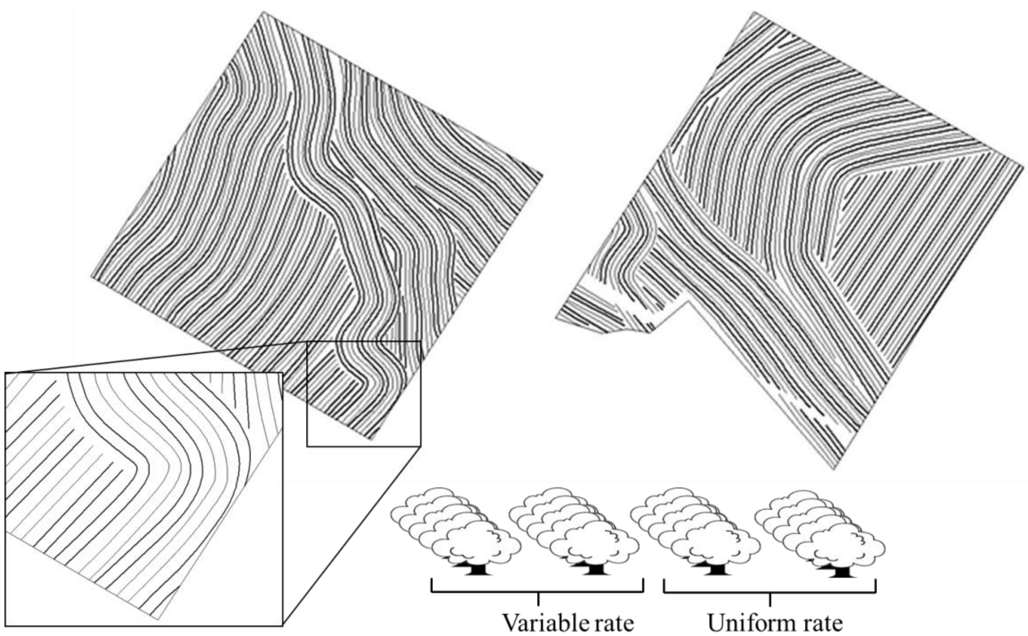

Fig. 1. Experimental fields divided into two treatments on intercalated pairs of tree rows

Soil fertility and nitrogen leaf nutrition (for nitrogen prescriptions) maps were obtained by using a sampling grid of two points per hectare. Soil and leaf samples were collected around these points in both treatments (Figure 2). Samples collected in the uniform treatment were used only for monitoring soil fertility, not for prescription purposes.

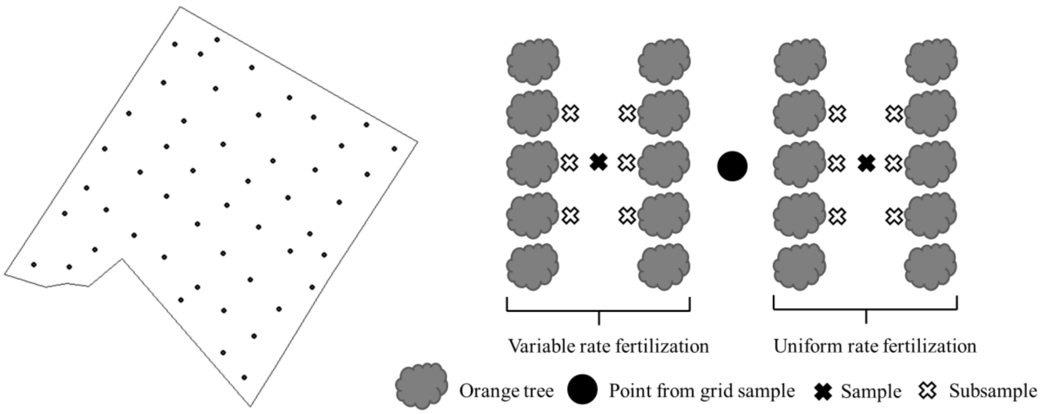

Fig. 2. Soil and leaf sample grid (left); sample and subsample collecting scheme (right)

Yield maps were generated every year for both treatments. The method was based on georeferencing of bags used during harvest. Yield values were calculated in each point based on bag volume and the number of trees needed to fill it up with fruit (representative area). Points in each treatment were interpolated separately generating the final yield map (Figure 3).

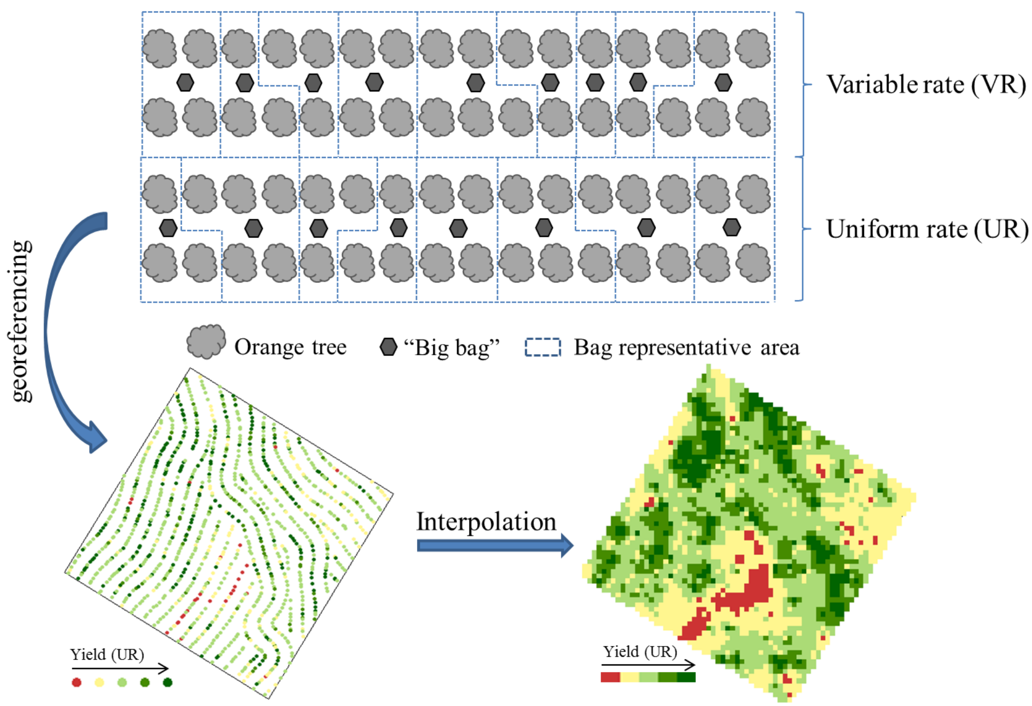

Fig. 3. Yield mapping steps (example for the uniform rate treatment): georeferencing of bags, calculation of yield and interpolation

Soil fertility, nitrogen leaf nutrition and yield maps were generated in a 10 x 10 m pixel scale. These maps were produced and arranged in SSToolbox ® 3.4 software (SST Development Group, Stillwater, OK, USA). Yield averages, levels of soil chemical attributes and the total input consumption were computed and compared between treatments.

Results in this paper cover five harvest seasons (2008 until 2012) and four fertilizations (2008 until 2011).

RESULTS AND DISCUSSION

Field spatial variability

Figure 4 shows the generated maps of altitude, clay content and soil EC. It is noticed that field 1 present higher spatial variability than field 2. A clear one direction gradient of altitude, soil texture and soil EC is view in field 1. Field 2 is more flat. It presents less variability in texture and less clay content. Soil EC reveals a small area with higher EC values, which matches with the lowest part of this field. This region is known for having soil drainage problems. The characteristics of spatial variability in these fields will further help interpretation of the results obtained in this study.

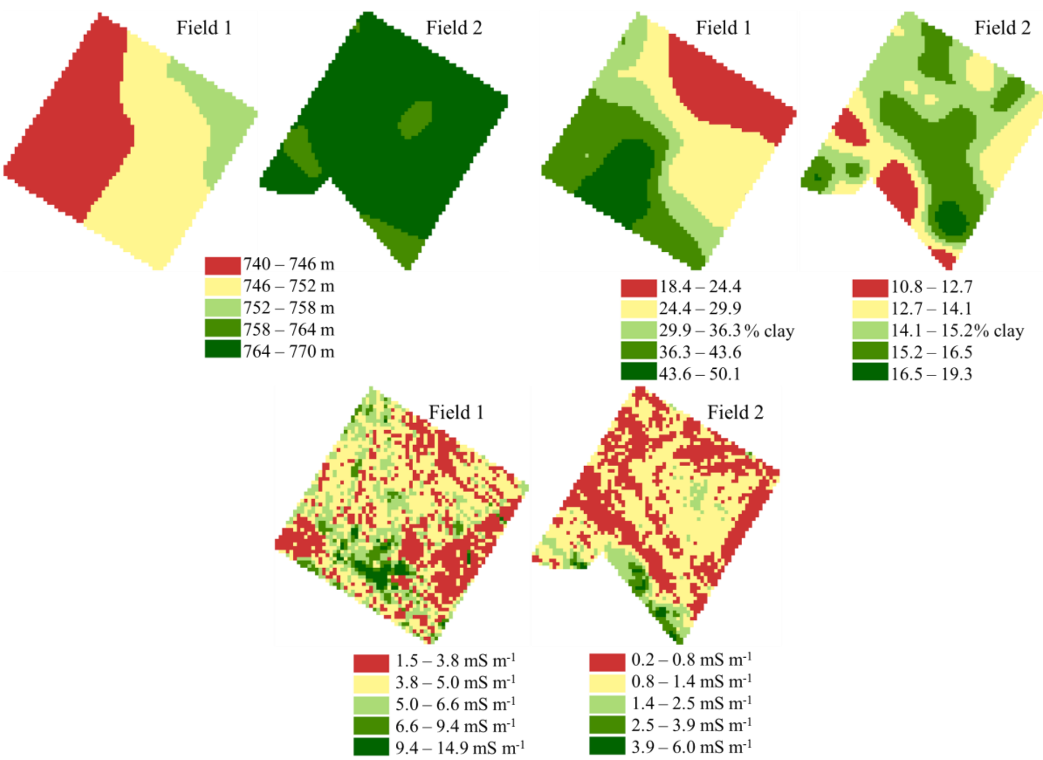

Fig. 4. Altitude, clay content and soil EC maps of the experimental fields

Input consumption

The amount of inputs used in each application, as well as the difference between treatments is viewed in Figure 5. It is noticed that usually variable rate applications provided input savings, mainly for N and K. For P application, savings of fertilizer in the VR treatment are usually followed by higher application in the next year. Reduction on lime consumption happened in the first field. In field 2, higher amount of lime was usually applied in the variable rate treatment. Overall results showed that after four years of application, site specific applications provided reduction on input consumption, mainly for N (37 and 51% less on field 1 and 2, respectively) and K fertilizers (41 and 18% less on field 1 and 2, respectively).

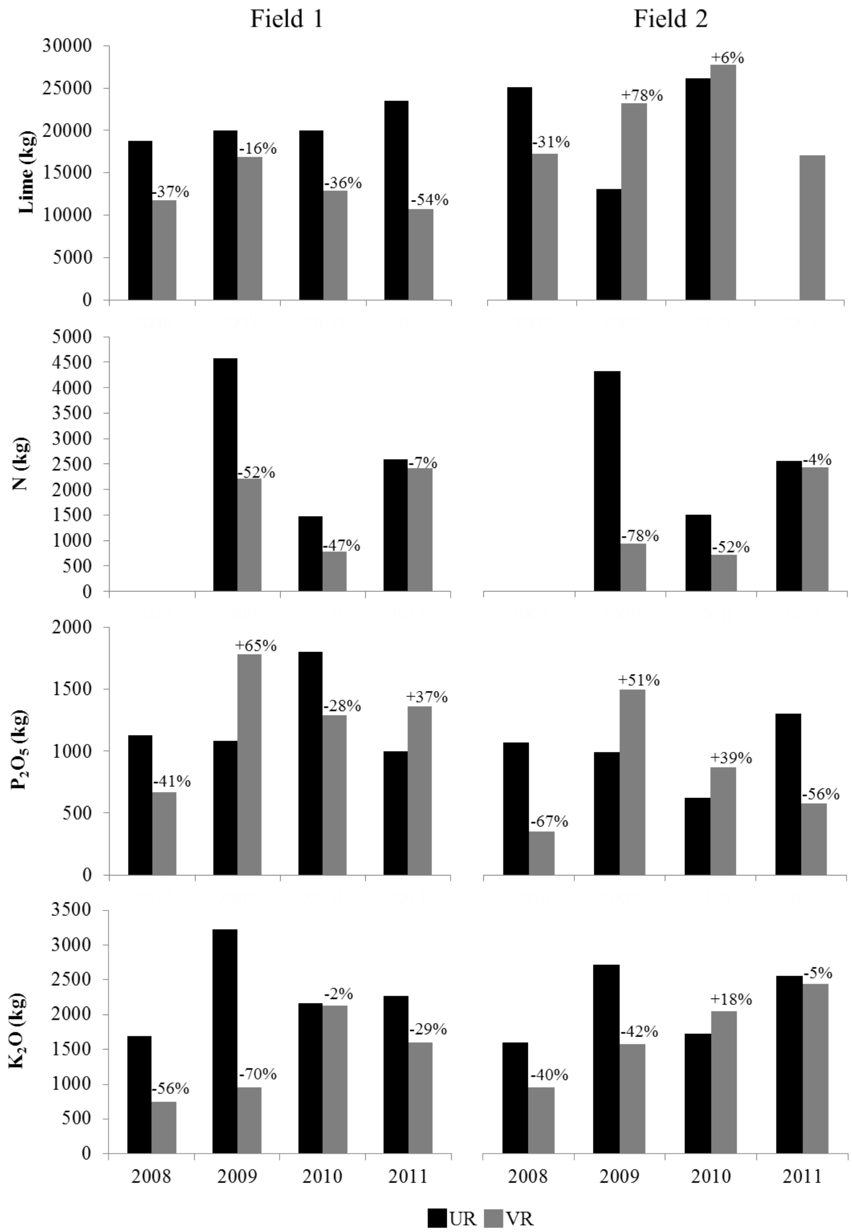

Fig. 5. Amount of inputs used in each variable and fixed rate application

The large differences on input consumption between treatments might be due to over simplification observed in the whole system of prescription and application used in the uniform application. Sampling procedure is less intensive, often leading to high difference on soil fertility levels when compared to the average values obtained by grid sampling in the same treatment. At the time of application it was common that only a few fertilizer formulas (N-P-K) are available for fertilization, so, some dosage simplification is also frequent. It is also observed that farmers often try to ensure soil fertility levels by applying higher fertilizer dosage than what is actually recommended in the official prescription charts. These facts combined lead to the differences on input consumption observed in this study as well as significant input savings.

Soil fertility

Soil fertility maps (P, K and base saturation - BS) for both treatments are viewed in Figures 6 and 7. They were classified according to interpretation classes from “very low” to “high”. “Median” levels are the goal for soil fertility management. “Low” and “very low” classes represent insufficient level of nutrients and “high” represents excessive levels.

In field 1, good result for soil fertility management was obtained in the variable rate treatment. It is noticed that variable applications were responsible for reducing areas of excessive K and base saturation levels, which reflects the less fertilizer consumption. This area (left portion of the map) is coincident with the higher clay content region. Uniform applications were unable to distinguish this variability and kept excessive nutrient levels in this portion along the years.

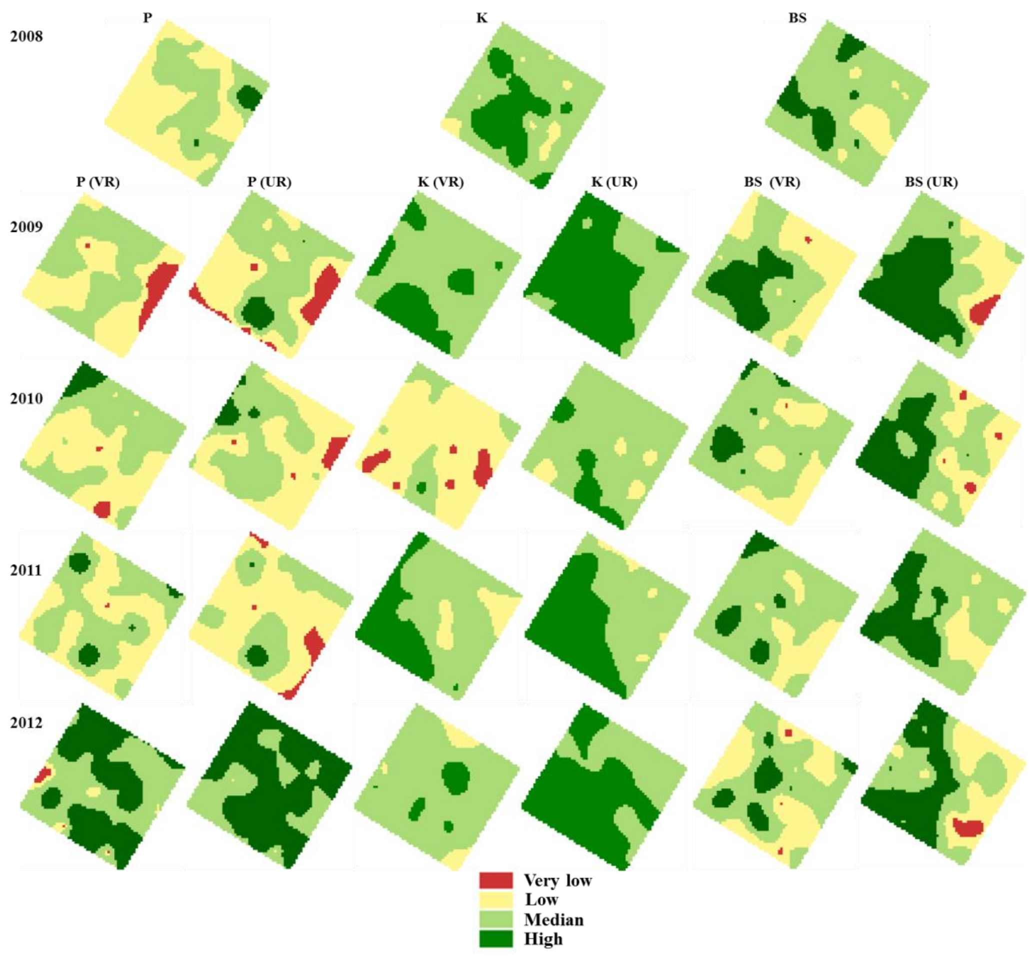

Fig. 6. Soil fertility maps for uniform and variable rate treatment in field 1

In field 2 it is observed lower levels of fertility (Figure 7). This field is naturally poorer than field 1. Variable rate management did not result as expected in this field, especially in 2009 and 2010 when lower levels of nutrient was found in this treatment. It was considered that intense input reduction in the first years of the experiment harmed soil fertility. The prescription equations used were considered not suited for this soil condition. In the following applications, higher doses of K were applied and soil maps became similar between treatments.

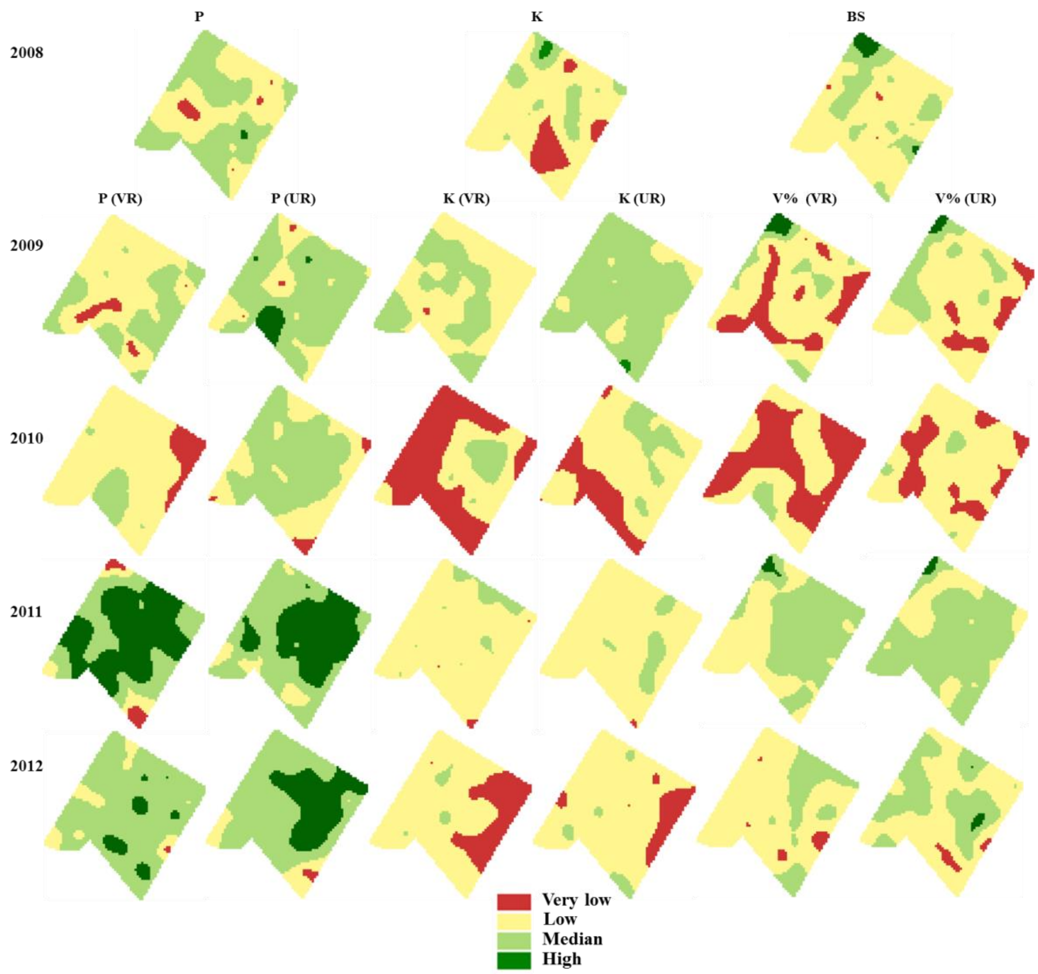

Fig. 7. Soil fertility maps for uniform and variable rate treatment in field 2

Yield

It is observed from the yield maps that both treatments performed similarly in most years (Figure 8). Some yield maps presented spatial variability in accordance to soil EC, texture and altitude maps. The spatial patterns are clear in 2008 and 2009 yield maps from field one (similar to altitude and clay content maps), and 2008, 2011 and 2012 in field 2 (similar to soil EC map).

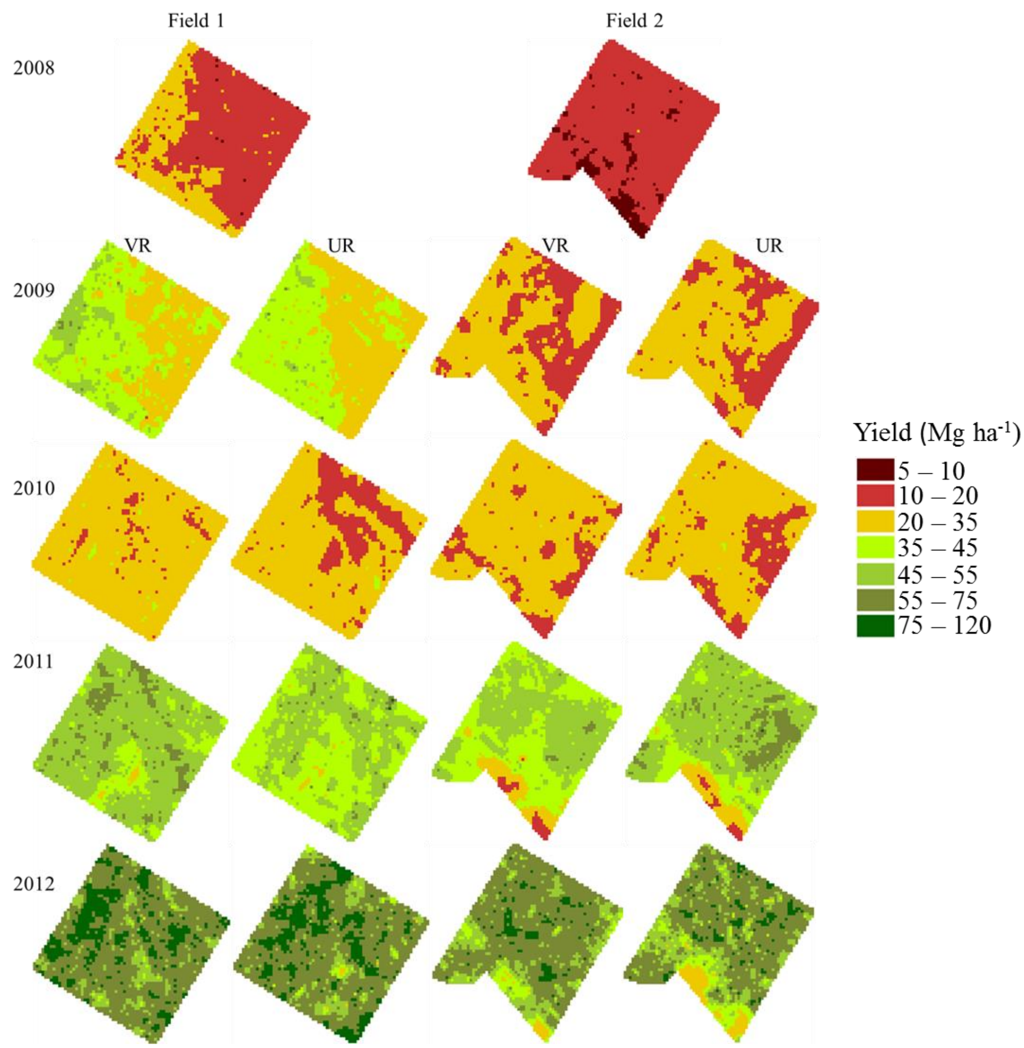

Fig. 8. Yield maps from uniform and variable rate treatment from 2008 until 2012

Although yield maps look similar between treatments through visual evaluation, the descriptive statistics shows that in some cases yield was influenced by the treatments (Table 1). In 2009, 2010 and 2011 average yield in field 1 was significantly higher (5 % significance level) in the variable rate treatment (6.7%, 13.1% and 8.1%, respectively). Higher yield averages in this field might be explained by the better spatial distribution of fertilizer in the variable rate treatment. Even when reducing fertilizer inputs, some parts of the field received higher amounts of fertilizer which might lead to higher yields. Also, the fertilizer delivery system of the equipment (under the tree's canopy) used for variable rate application might have helped efficiency of fertilization.

On the other hand, lower average yield was observed in 2009 and 2011 in the second field, which might be due to lower levels of soil fertility found in this treatment.

Table. 1. Descriptive statistics of yield data

Field	Year	Treatment	Yield			
			Average (Mg ha^{-1})	CV (%)	Min (Mg ha^{-1})	Max (Mg ha^{-1})
1	2008	-	16.62	26.49	3.45	43.08
	2009	Variable	36.52*	23.26	3.02	81.44
		Uniform	34.22*	22.20	11.13	79.27
	2010	Variable	23.45*	24.98	9.03	45.15
		Uniform	20.72*	26.20	5.11	46.29
	2011	Variable	49.46*	16.42	20.67	93.02
		Uniform	45.73*	16.06	21.39	85.55
	2012	Variable	64.53	26.22	32.47	120.58
		Uniform	64.70	29.01	21.31	145.48
2	2008	-	12.45	20.93	3.24	25.95
	2009	Variable	20.97*	19.14	9.24	35.26
		Uniform	21.63*	19.24	8.88	35.51
	2010	Variable	22.80	19.84	7.29	39.56
		Uniform	23.54	23.72	8.51	51.08
	2011	Variable	45.27*	18.84	8.27	74.39
		Uniform	49.04*	19.21	11.98	85.37
	2012	Variable	58.74	25.05	22.06	110.61
		Uniform	58.16	30.37	17.24	129.23

CONSLUSION

Variable rate technology for fertilizers and lime applications was evaluated in a long term experiment in two citrus orchards in São Paulo, Brazil. Fields were divided into variable and fixed rate fertilizer strip treatments. Variable rate prescriptions were based on soil and leaf grid sampling and yield data. Fixed rate applications followed standard prescriptions based on soil sampling and yield expectation. Data of soil fertility, input consumption and yield were collected for both treatments from 2008 until 2012.

Variable rate applications provided significant input savings, mainly for N and K fertilizers. Better soil fertility management was obtained in one of the fields, since areas with excessive level of nutrients were reduced. In the same field, yield increase was found in three evaluated years. This field presented good potential for PA management since high spatial variability was found for soil texture and altitude which influenced in yield and soil fertility variation.

In the second field, loss on soil fertility and yield was found on the site-specific management in two out of the four years of variable rate applications. This field presented lower natural nutrient fertility and the variable rate prescriptions used were considered not suited for this soil condition.

Overall results were better for the field with higher variability. This study showed the potential of variable rate technology to increase yield and improve soil fertility management.

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