VARIABLE RATE FERTILIZATION FOR CITRUS

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ABSTRACT

To improve economic and environmental sustainability new management strategies has been considered to citrus production. Especially on grain crops, Precision Agriculture (PA) has proved to be a successful tool to manage crop fields according to their variability, mainly through variable rate (VRT) fertilization practice. Although VRT technology is already being used on commercial citrus orchards, few academic researches have approached the impact of VRT fertilization on inputs consume and on fruit yield in a long-term study. The objective of this work was to evaluate VRT fertilization on citrus and its impact on fertilizer consume, fruit yield, soil fertility and plant nutrition, and compare the results to fixed rate fertilization. Data from two harvest seasons were collected on two 25.7 ha adult orange groves, located in São Paulo State, Brazil. In each field, two treatments were implanted entitled "variable rate fertilization" and "uniform rate fertilization". They were placed in interposed pairs of tree rows. Soil and leaf chemical attributes were mapped separately for each treatment on a grid sample of two points ha^{-1}. Yield mapping followed procedure based on georeferencing of the bags used on harvest. VRT prescriptions of nitrogen, phosphorus, potassium and lime were applied on the variable rates treatment rows. VRT application provided savings of lime, nitrogen and potassium fertilizers. After fertilization, soil maps on VRT rows showed reduction of regions with excess of nutrients but also the lower rates used on variable prescription resulted in increased areas of low nutrient levels on a sandy soil. Yield and leaf nutrition maps revealed no significant difference between VRT and fixed rate fertilization. Results confirmed the benefit of VRT fertilization for citrus because it optimized inputs use without compromising yield or plants nutrition. Further data collection and analyses is required to assess long term effects of VRT on the crop.

Keywords: variable rate fertilization, input consume, citrus yield map

INTRODUCTION

Variable rate technology (VRT) is an essential site-specific tool for Precision Agriculture (PA) management. It allows input application on variable doses within a field according to the crop and soil spatial variability. It results in a more rational use of inputs and less environmental harm. This type of management can be applied to any input or crop, but certainly it has been more frequent on grain crops and on fertilization operations. Although it is not yet the main fertilization practice adopted by growers its concept is quite known and accepted.

Among perennial crops, citrus represents an outstanding potential for PA. Orange juice is an important commodity throughout the world and supports a very complex industry of orange production, processing and distribution system. According to the Food and Agriculture Organization of the United Nations (FAO, 2012) nearly 40% of the world orange production came from Brazil (28%) and United States (11%) on 2010. The two countries cultivate 840 thousand ha and 260 thousand ha of orange orchards, respectively (FAO, 2012). Production areas are concentrated in São Paulo and Florida states. All field production demand great amount of chemical inputs and fossil derived products, so any technology that provides input optimization is desirable for economic and environmental purposes.

Both production regions have tested VRT and other PA practices either on research or on field trials. Florida citrus has already tested and developed several site-specific technology. Yet in the early stages of PA, Whitney et al. (1999) pointed out the potential of this management strategy due to high yield and canopy variation. Their initiative inspired researchers to develop canopy size sensors which allows VRT fertilization at single tree basis (Zaman and Schumann, 2005; Wei and Salyani, 2006; Schumann et al., 2006a). For São Paulo state condition, citrus orchards are fairly uniform concerning canopy size, because trees are renewed periodically. On the other hand, high spatial variability can be found on 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).

If spatial variability is acknowledged, site-specific tools clearly provide better management practices, but few researches tried to measure its true benefits over traditional practices and its impact on citrus crop. Miller et al. (2005) and Schumann et al. (2006b) evaluated the field performance of VRT granular fertilizer spreader. 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. Results of yield response to variable rate fertilization were showed by Molin et al. (2010) for a coffee production. They created an innovative method of comparing VRT to single rate applications by placing treatments on intercalated tree rows. This method seems to be suitable for any perennial tree crop. Results showed 23% savings on phosphate fertilizer and 13% increase on potassium fertilizer when using VRT. Yield was increased on 34%.

Input consume on variable rate fertilization and its effect on yield, soil and plant characteristics are essential information for growers who intend to adopt PA on citrus, knowing that this management strategy would require monetary investment, increase complexity and operational costs. Long term study and appropriate experimental methodology is required to achieve consistent conclusion about the benefits of PA over traditional methods. So, the objective of this work is to compare the variable rate with fixed rate fertilization on citrus concerning their effects on input consume, fruit yield, soil fertility and plant nutrition.

MATERIALS AND METHODS

This study was conducted on two 25.7 ha orange groves located in São Paulo state, Brazil, during 2008 and 2009 harvest seasons. Trees were planted on 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 on the first field and 7.5 m x 3.5 m on the second. Both orchards are non-irrigated.

Two treatments were entitled variable rate and uniform rate fertilization. They were placed on intercalated pairs of tree rows, based on methodology proposed by Molin et al. (2010) (Figure 1). On 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. On uniform rate, fertilizer and lime applications were carried out on a single rate throughout the field, according to traditional prescription used by growers. It is based on a single soil and leaf sampling and yield estimative for the field.

Both treatments used the same prescription equation and differ only on sampling and on the application method. Doses of potassium and phosphorus fertilizer were calculated according to the soil levels of these elements and expected yield. For nitrogen fertilization, instead of soil levels we used nitrogen

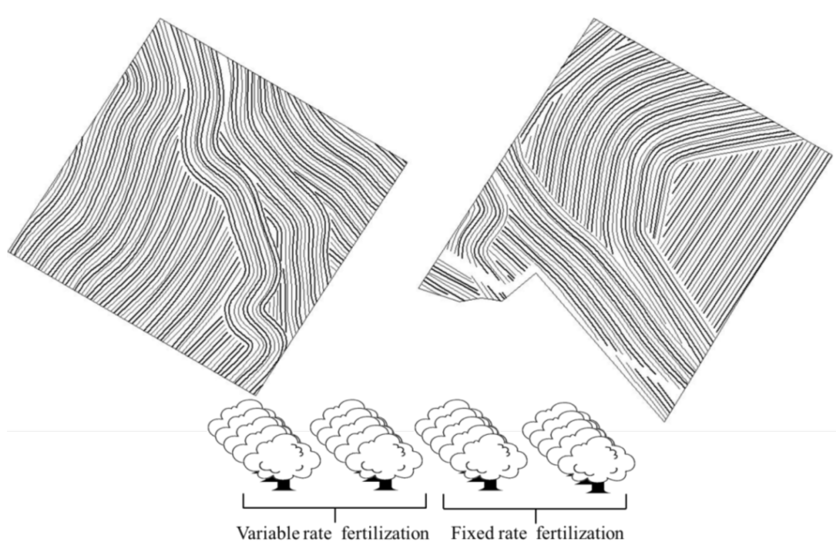

Fig. 1. Experimental fields divided into two treatments on intercalated pairs of tree rows.

leaf content by leaf sampling. Rates of lime were calculated based on soil base saturation and cation-exchange capacity.

Soil fertility and leaf nutrition were mapped by sampling on a two samples ha^{-1} grid. On each point of the grid samples were collected on the two treatments separately. Yield mapping followed procedure based on georeferencing of bags used on harvest. The information about estimated orange volume and the number of trees needed to fill up each bag were collected to calculate yield and generate yield maps. Mapping these factors on the variable treatment served to create prescription maps as well as to verify the effects of application on the further harvest season. Maps from the uniform treatment served only as a result of traditional fertilization and were not used for prescription purposes.

Averages from yield, levels of chemical attributes on soil and leaf and the total input consumed were compared between treatments.

RESULTS AND DISCUSSION

The total amount of fertilizers and lime actually used during 2008 and 2009 applications are shown on Table 1. In 2008, single rate nitrogen application was used in the entire field because leaf sampling did not happened previously, which is necessary to elaborate variable nitrogen prescriptions. It is noticed that generally variable rate application provided significant savings of inputs, except for phosphorus applications on 2009 (Table 1).

Sampling method, yield mapping, machine calibration and rate accuracy help explain the large difference of input consume between treatments. Besides that, growers normally tend over prescribe fertilizer rates as a safety management strategy. Also fertilizer formulas of N, P and K, which were used on the uniform treatment, rarely attend exactly the calculated proportion of these elements for fertilization.

Table 1. Input consume during variable and uniform rate fertilization.

Field	Treatment	------------ 2008 ------------				---------------- 2009 --------------			
		N	P_2O_5	K_2O	Lime	N	P_2O_5	K_2O	Lime
					- kg -				
1	Variable	-	671	751	11800	2210	1783	952	10000
	Uniform	-	1128	1692	18750	4578	1080	3224	20000
2	Variable	-	351	958	21900	940	1501	1571	11000
	Uniform	-	1068	1602	25000	4332	993	2716	13000

Soil fertility maps from 2008 represents the first soil condition when the experiment started (Figure 2). Soil sampling in 2009 generated two maps, one for each treatment. They represent the soil fertility after the first applications (during 2008) and some of the information used for the later variable rate fertilization in 2009 (Figure 2). Maps classes followed Raij et al. (1997), where the target level for appropriate soil fertility is “median”.

As lower rates were applied on the variable treatment, its soil maps showed lower levels of the elements. On the first field it is noticed that regions of high levels of nutrients were reduced to a median level, which is desireble (Figure 2). On the second grove soil is chemically pooer than in the first one, once it presents a predominant sandy texture. In this case levels below "median" were found more often on variable rate treatment (Figure 2) probably due to an unexpected yield increase that exported a significant amount of soil nutrients on 2009 season (Figure 3). So the higher fertilizer rates used on unform application resulted on a more adequate soil fertility on this grove.

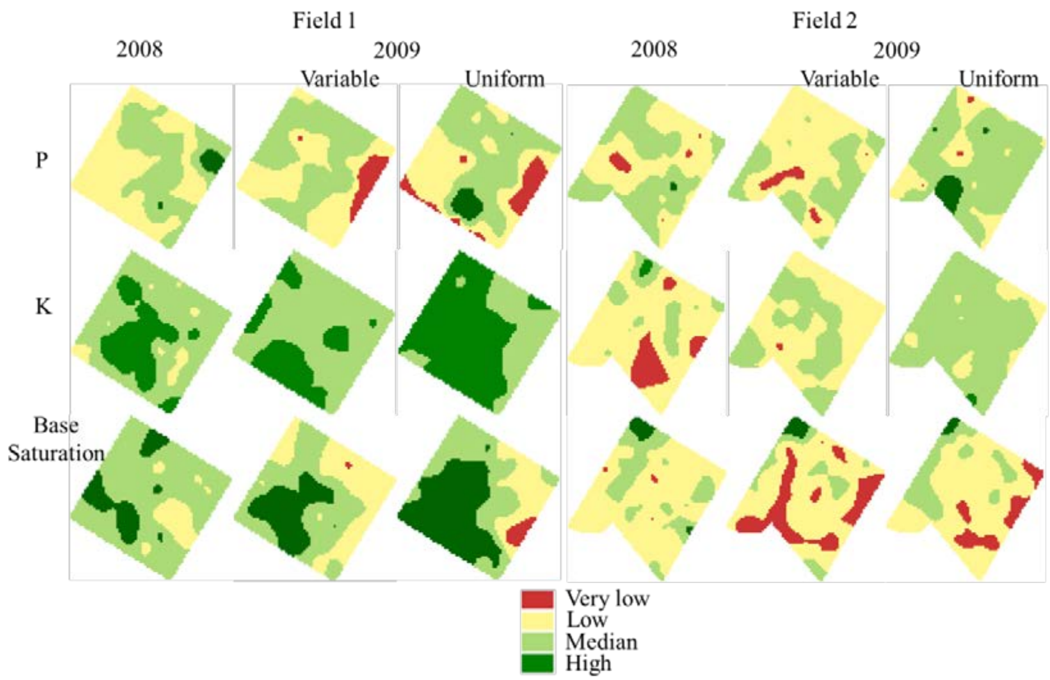

Fig. 2. Soil fertility maps from a 2 samples ha^{-1} grid based on four classes (Raij et al., 1997).

Even with reduced fertilizer rates in 2008, variable treatment did not affected leaf nutrition once nutrient concentrations from 2009 leaf sampling were similar between treatments (Table 2). The coefficients of variation found on 50 georeferenced samples were often very low evidencing low spatial variability. According to classification of Quaggio et al. (1997), average levels were excessive for all elements and treatments, which indicate that previous fertilizations occurred on excessive doses.

Yield data (Table 3) showed a great yield increase from 2008 to 2009 on both fields due to trees growth and favorable climate conditions. There was no significant difference on yield between variable and uniform fertilization. Coefficients of variation were also similar between them. It indicates that site-specific management did not affect yield spatial variability on the first year after variable rate applications. Yield maps also showed similarity from variable and uniform treatments (Figure 3).

Table 2. Level of leaf nutrients from 50 sampling points in 2009 season.

Field	Element	Treatment	Average ($g\ kg^{-1}$) *	CV (%)	Min. ($g\ kg^{-1}$)	Max. ($g\ kg^{-1}$)	Average level **
1	N	Variable	29.58 a	5.98	26.20	33.50	excessive
		Uniform	29.64 a	5.66	25.90	33.20	excessive
	P	Variable	1.80 a	7.24	1.50	2.20	excessive
		Uniform	1.73 a	6.85	1.50	2.00	excessive
	K	Variable	17.32 a	10.37	13.70	21.70	excessive
		Uniform	17.56 a	11.09	11.50	20.50	excessive
2	N	Variable	30.12 a	5.81	27.20	33.70	excessive
		Uniform	29.93 a	5.27	27.00	33.40	excessive
	P	Variable	1.66 a	8.59	1.40	2.20	excessive
		Uniform	1.71 a	8.10	1.40	2.00	excessive
	K	Variable	15.25 a	19.55	10.30	23.00	excessive
		Uniform	16.29 a	18.91	8.50	22.90	excessive

* Values followed by the same letter are not different between treatments, at 5% significance.
** Interpretation classes from low, adequate to excessive levels (Quaggio et al., 1997).

Table 3. Fruit yield during two harvest seasons.

Harvest season	Field	Treatment	Area (ha)	Average ($t\ ha^{-1}$) *	CV (%)	Min. ($t\ ha^{-1}$)	Max. ($t\ ha^{-1}$)	Total (t)
2008	1	-	25.70	18.68	22.02	5.47	43.65	427.01
2009	1	Variable	12.85	41.85 a	14.90	20.17	66.98	498.20
2009	1	Uniform	12.85	42.88 a	14.55	23.71	67.08	473.25
2008	2	-	25.70	14.61	18.14	5.22	28.42	320.04
2009	2	Variable	12.85	33.56 a	11.13	17.97	47.21	353.63
2009	2	Uniform	12.85	34.17 a	12.10	20.89	58.33	372.31

* Values followed by the same letter are not different between treatments, at 5% significance.

Further data collection and analyzes are needed and application of variable rate fertilization has continued on these groves. Data from 2010 and 2011 have been collected but still not completely processed. As a perennial crop more harvest seasons must be studied so the long term effects of VRT fertilization can be perceived. This project intends to gather data from six harvest seasons and five consecutive variable rate fertilizations, ending in 2013.

Large scale field trials have started in other groves and different experimental designs are also been tested.

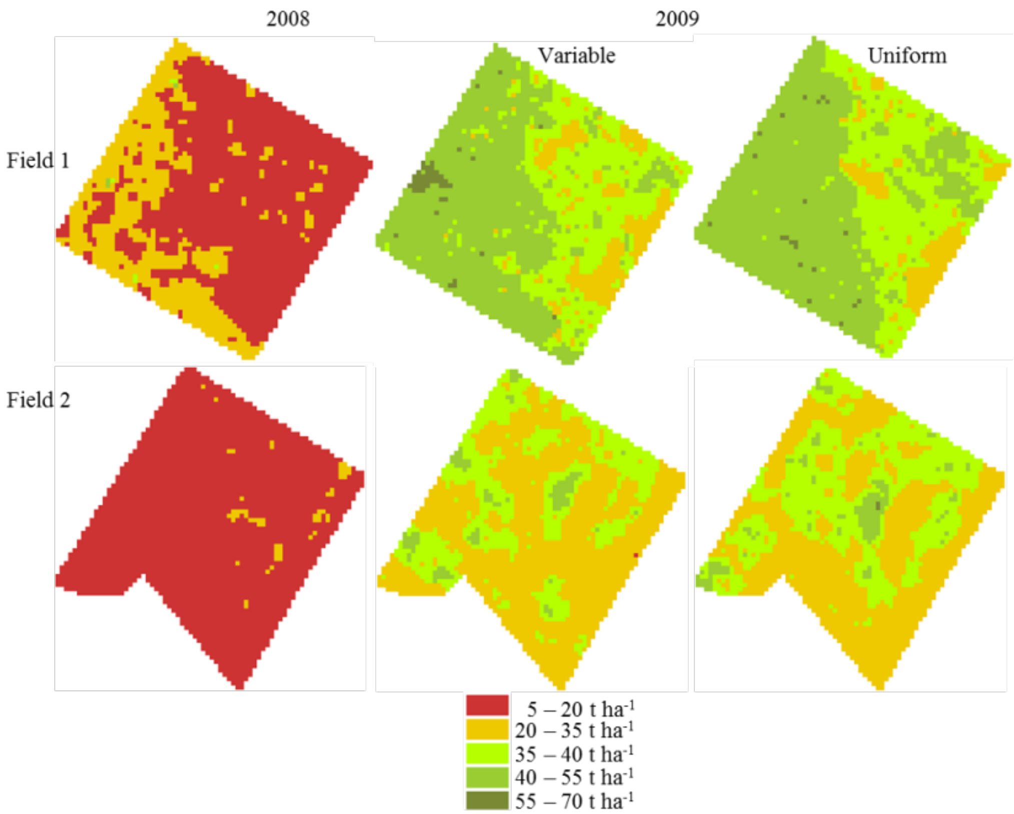

Fig. 3. Orange yield maps before treatments implementation (2008) and after variable and uniform fertilization (2009).

CONCLUSION

Variable rate fertilization enabled optimization of input use on an orange crop. This strategy provided significant savings of nitrogen, potassium and lime once it uses a more accurate sampling method and equipment; traditional prescription tends to overestimate fertilizer rates. Variable rate applications decreased levels of nutrient in the soil. It reduced regions of over concentration of elements but also increased regions of low levels of phosphorus and potassium on a sandy soil. Leaf nutrient concentration indicated previous over fertilization once excessive levels of N, P and K were found trough sampling. Ether plant nutrition or fruit yield were not affected by variable rate fertilization.

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