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Nutrient Balance in Organic Raspberry Production with Dairy-manure Amendments

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Authors' contributions

This work was carried out in collaboration between all authors. All authors designed the study. Authors JLF, EEM and MVC conducted sampling of soils and plants, autor JLF performed the chemical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Raspberry (*Rubus ideaus*) is a perennial crop that reaches commercial production after 4 to 5 years since planting. To improve of Raspberry crop production, fertilizers and manures are applied to the soil. Many farms in the Andean-Patagonian region produce organic crops, and apply manure obtained from complementary activities. A nutrient balance was studied in a raspberry crop amended with dairy manure since a decade by comparing continuously amended plants with respect to plants where amendment was suppressed. Soil nutrient concentrations of the crop area were compared with a nearly non-cultivated soil. The manure had a strong effect on phosphorus (P-Olsen), values being much higher than in pristine soils, around 60 mg kg^{-1}, considered limit value to avoid soil P movement. The concentration in raspberry leaves exceeded 7 g kg^{-1} and 24 g kg^{-1} for K and N, respectively. There was a strong increase in the nutrient uptake from flowering to ripeness according to an increase of dry matter from 2196 kg ha^{-1} to 4791 kg ha^{-1}. A slight dilution effect (nutrient concentration declines as the crop grows) of N, P and K in plants was observed. The nutrients added by the manure and nutrients returned to the soil by pruning resulted in a positive balance. A reduction of the quantities of manure may be applied in the last years of raspberry crop production.

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Keywords: Rubus ideaus; requirements; mineral elements; soil.

1. INTRODUCTION

Fine-fruit production is very important for local economies of the Andean–Patagonian region, of Argentina, and includes a set of species that are characterized by small size among which we find the berries: blueberry (*Vaccinium corymbosum*), redraspberry (*Rubus idaeus*), black berries shrub (*genus Rubus hybrid*), gooseberry (*Ribes grossularia*), cassis (*Ribes nigrum*), corinth (*Ribes rubrum*), strawberry (*Fragaria ananassa*) and cherries: wild cherry (*Prunus avium*), sour cherry (*Prunus cerasus*). The most important fine-fruit crop is raspberry, a perennial crop, with biennial shoots (canes) that are vegetative (primocanes) in the first year and reproductive (floricanes) in the second year [1]. This species reaches commercial production 4 to 5 years after planting and plants may remain productive for over 20 years. Fruiting occurs in the lateral branches that grow from buds at the nodes of the canes. After fruit harvest, floricanes are pruned and the primocanes are thinned out (ten per linear meter). In some farms, the pruned biomass is mixed into the soil between rows through superficial tillage, while in other farms it is removed and burnt.

In the Andean region, more than 30% of the total fine fruit production is organic [2]. The organic products industry is gaining popularity among consumers because of increased demand of healthier foods and the perception about the environmental benefits of the agricultural practices associated with organic production [3]. It has been suggested that organic farming systems are a valid alternative production approach which yields agronomic and environmental benefits, particularly with regard to the improvement of soil quality [4]. Organic farming systems emphasize reliance on ecological interactions and biological processes over direct intervention. Therefore, the input of imported materials into the system to build and maintain soil fertility is restricted [5], considering soil fertility as the ability of a soil to provide nutrients to crops [4]. Principles laid down by the International Federation of Organic Agricultural Movements [6] specify that organic farms must avoid agricultural pollution, including habitat protection [7].

Amendments, such as fertilizers, manures and composts, are generally applied the soil to make up for any nutrient deficiency that could occur [8], although an inadequate or excessive application of nutrients to raspberry fields, either as fertilizers or manures, can have both economic and environmental implications [9]. Many organic farms in the Andean-Patagonia region produce their own manure generally from complementary activities such as dairy farming. However, in general, manure is applied according to their availability, evaluating neither the amount of nutrients supplied by manure nor the extraction of them by the crops. However, achieving a balance between inputs and outputs of nutrients within the farm system is critical to ensure both short-term productivity and long-term sustainability [5]. Dosing of manure application requires knowledge of the bulk density, moisture and nutrient concentrations of this material; crop nutrient requirements and the soil capacity to retain or release nutrients. To study nutrient dynamics during crop cycle, the analysis of the different plant parts (leaves, canes, lateral branches, and berries) has been recommended [10,11].

The objectives of this study were: 1 – to quantify nutrients in the soil, plants and manure to evaluate whether the amount of manure applied was according to raspberry crop requirements, 2 – determine whether the suppression of manure reduces yield crop, indices of vigor and leaf nutrient concentration, 3 – to assess changes in soil fertility levels due to manure application by comparing a pristine soil with a cultivation soil after having received long-term application, considering the soil thresholds suggested in the bibliography.

2. MATERIALS AND METHODS

2.1 Study Site and Experimental Design

The experiment was conducted on an organic farm dedicated to the production of fine fruit and dairy near El Bolsón, southern Argentina (41º 56´ 36´´ S, 71º 31´21´´, 300 m above sea level), mean annual temperature is 10 °C and mean annual rainfall is 900 mm [12]. The soil is classified as Vitrandic Hapludoll (USDA). Natural vegetation (pristine soil) is composed of sub-shrubs of *Acaena splendens* and *Baccharis magellanica*, shrubs of *Fabianaimbricata* and *Discaria articulata* and isolated trees of *Austrocedrus chilensis* [12,13].

The area used was 1 ha on a 10 years old raspberry crop (var. Tulameen) which had been annually fertilized with dairy manure produced in the same farm at a rate 58.5 m^3 ha^{-1}. The manure was usually mixed with woodchips and stored outside in piles approximately 1.5-2.0 m high by 30 m long, which remained in the field for 3 to 12 months prior to application. The statistical design was randomized complete block with three replications. Treatment levels of factors were: continuous manure application (CM) (58.5 m^3 ha^{-1}) and manure suppression (0 m^3 ha^{-1}) during two production season (SM). The crop was irrigated and spontaneous inter-row vegetation had been cut every two weeks at 10-20 cm height. Crop plant density was 10 plants m^{-1} and crop rows were 3.3 m apart. In each block, one crop line of 9 m for CM and one crop line of 9 m for SM and soil at both sides of the line were randomly selected. The manure was applied in the inter-row space during the beginning of the growth season.

The soil of an area under natural vegetation of approximately of 1 ha, never cultivated nor manured (pristine soil, PS) near to the raspberry crop (about 20 m far) was also sampled and used as control for the experiment.

2.2 Soil Sampling and Analyses

Soil sampling wa**s** performed at the following phenological stages: growth season start (10/04/2006), flowering (11/30/2006), fruit maturity (ripeness) (01/24/2007), and dormancy (5/14/2007). Composite soil samples were taken from the two inter-row spaces of each treatment line (CM and SM) at 0-20 cm, 20-40 cm and 40-60 cm depths. Three composite samples were also taken from the pristine soil (PS) at the same depths and sampling dates than cultivated soil. The following soil analyses were performed according to [14]: pH in water (1:2.5), electrical conductivity (EC) (1:2.5), organic carbon (OC, Walkley and Black), total N (N, Kjeldahl), Nin (inorganic nitrogen, amonium plus nitrates) extracted in KCl 2M and determined by steam distillation with MgO and Devarda´s alloy, P extracted in $NaHCO_3$ 0.5M (P-Ol, Olsen) and determined by the molybdate-ascorbic acid method, cation exchange capacity (CEC) and exchangeable cations (Ca, Mg, K) in NH_4OAc 1M followed by atomic absorption spectrometry determination. The pH was also measured in 1:50 1 M NaF solution after 2' and 60' [15], and phosphate retention was determined by [16]. The main soil parameters determined at the beginning of the experiment can be observed in Table 1.

2.3 Plant Sampling and Analyses

In the CM, plant samples were taken at the following phenological stages: flowering (11/30/2006), fruit maturity (ripeness) (01/24/2007) and dormancy (05/14/2007). At each stage, 5 plants were taken outside of the central 4 m used for evaluation of yields. Samples were partitioned in cane, lateral branches, leaves and berries in floricanes and cane and leaves in primocanes, then dried at 60ºC and ground to 1 mm. Pruning dry matter and nutrient concentrations were also determined in the CM treatment (02/23/2007) by collecting pruned material (prior to incorporation in to the soil) from a surface of 1.5 m^2 of each replication.

To compare nutrient concentration of CM and SM treatments, composite samples of 30 leaves were taken from primocanes and floricanes at a height of 50 cm of each replication at flowering (11/30/2006). Fruit yields (fresh weight and moisture percent) of CM and SM treatments were measured during January 2007 and January 2008 in the central 4 m of the 9 m of each replication. After the harvest of 2008 vigor indices (number of lateral branches, length and diameter (50 cm height) of floricanes) were also determined.

The analyses conducted in plant tissue were: N by Kjeldahl digestion and P, Ca, Mg and K by dry digestion at 550ºC and HCl extraction, followed by determination of P by the molybdate ascorbic method, and Ca, Mg and K by atomic absorption [17,18]. The amount of each nutrient absorbed by the crop aboveground biomass (kg ha^{-1}) was calculated by multiplying the nutrient concentration by the dry matter of each plant part and considering a total number of 30300 plants ha^{-1}.

2.4 Manure Determinations

Ten composite samples were taken from the manure spreader container during the firts day of its application and analyzed as mentioned above for plant tissue (Table 2). Besides, pH and electrical conductivity were determined in water (ratio 1:5 manure: water). For bulk density determination, six additional composite samples were taken and placed in a 1199 cm^3 container. Fresh weight was registered and then the material was dried at 60ºC. Bulk density (dry weight* volume^{-1}) and water content: (wet weight - dry weight)* wet weight^{-1} *100) were calculated. The total amount of nutrient applied was calculated from the data of bulk density, the concentration of nutrients and the volume of manure ha^{-1} applied (Table 2).

2.5 Statistical Analyses

For comparison of soil variables between CM and SM treatments, ANOVAs was realized. Model assumptions (residual normal distribution, residual homogeneity, no interaction among blocks) were checked and mixed models were used for analyses, taking into account the correlation between sampling dates.

For comparison between cultivated soils (CM and SM) and PS, a multiple comparisons test (Tukey) between each date of CM and SM, and the average of the dates of PS was used at 5% significance level (in the case of complying with the requirements of model).

For comparisons of plant dry matter accumulation and nutrient concentration between flowering and maturity in CM plots, ANOVA was performed, taking into account the correlation between sampling dates. Significant differences were calculated for variables that meet model requirements (N, P, K). Ca and Mg did not meet the model requirements, thus, significant differences were not calculated.

For fruit yield (January 2007) and fruit yield and vigor indices (January 2008) to compare CM and SM, analysis ANOVA were performed, after model assumptions were checked.

Statistical analyses were performed using Infostat (1998-2008) programs [19].

3. RESULTS

3.1 Soil

Extractable soil Ca, Mg and K did not show an significant difference between CM and SM during the entire growing season. Significant differences were found between PS and the other treatments (CM and SM) only for extractable soil K in flowering at 0-20 cm and 20-40 depths (Fig. 1).

No significant differences were found for Nin (inorganic nitrogen, amonium plus nitrates) at 0-20 cm, 20-40 cm and 40-60 cm depths among CM and SM plots. Significant differences for Nin were found between PS and the other treatments (CM and SM) in flowering at 0-20 cm depth. No excessive values were found of Nin during the growing season at different depths (Fig. 2).

No significant differences were found for P-Ol at 0-20 cm, 20-40 cm and 40-60 cm depths among CM and SM plots. Significant differences for P-Ol were found between PS and the other treatments (CM and SM) during the whole growing season at 0-20 cm depth and flowering at 20-40 cm depth and 40-60 depth (Fig. 2). Very high levels of P-Ol (around to 60 mg kg^{-1} on average) were found in the CM and SM plots at 0-20 cm depth.

3.2 Plant

The observed increases in nutrient absorption by the crop (Fig. 3) corresponded to increases in dry matter from 2196 kg ha^{-1} at flowering to 4791 kg ha^{-1} at ripeness (a significant difference was found in total plant dry matter accumulation).

The N, P and K concentrations decreased slightly between flowering and ripeness (Table 3).

Nitrogen, K and Ca (in this order) were the most extracted nutrients raspberry crop (Fig. 3). The leaves of floricanes were the plant organs with the highest level of nutrient accumulation at ripeness (36% N, 28% K, 43% Ca, percentages are quantities of each nutrient in floricanes leaves compared to whole plant in ripeness). The next highest were the berries (22% N, 28% K, 14% Ca, idem).

Nutrient contents in the pruned vegetation of the raspberry crop can be observed in Table 4.

The proportions of nutrient returned to the soil by pruning (Table 4) with respect to total nutrient absorbed by the crop at ripeness (Fig. 3) were: 50% N, 32% P, 92% Ca, 42% Mg and 49% K.

The ratio of nutrients applied with respect to the manure (Table 2) and total nutrient absorbed by the crop at ripeness (Fig. 3) were: 1.4 N, 4.7 P, 3.9 Ca, 5.5 Mg, 3.5 K.

No statistically significant differences were found between CM and SM in nutrient concentrations in leaves of primocanes and floricanes at flowering (Table 5).

Table 1. Caracterization of studied soils: bulk density (BD), pH in water, pH in NaF, electrical conductivity (EC), phosphate retention (P-Ret), organic carbon (OC), nitrogen Kjeldahl (N), cation exchange capacity (CEC)

Depth (cm)	BD (Mg m^{-3})	pH-H_2O	EC (dS m^{-1})	pH-NaF 2`	pH-NaF 60`	P-Ret (%)	OC (g kg^{-1})	N (g kg^{-1})	CEC ($cmol_c$ kg^{-1})
0-20	1.12	6.2	0.15	8.5	9.2	15	45	3.6	28.5
20-40	1.22	6.2	0.08	8.6	9.2	18	31	2.6	25.9
40-60	1.22	6.3	0.06	8.4	9.1	23	21	1.9	22.5

Table 2. Caracterization of studied manure: pH in water, electrical conductivity (EC), Moisture (H), bulk density (BD) and concentration of nutrients in dairy manure. Amounts of nutrient (kg ha^{-1}) for 58.5 m^3 ha^{-1} of manure applied, considering the nutrient concentrations and BD in the manure

Manure	pH	EC	H	BD	N	P	Ca	Mg	K
		(dS m^{-1})	(%)	(Mg m^3)		----------------------(g kg^{-1})-------------------------			
	8.4	3.2	69	0.18	8.5	2.8	11.2	4.9	14.1
						---------------------(kg ha^{-1})-----------------------			
					89.5	29.5	117.9	51.6	148.5

Table 3. Concentration of nutrients in raspberry crop in continuous manure (CM) at flowering, ripeness, dormancy. In N, P and K one asterisk indicates significant differences between flowering and ripeness (P<0.05), n indicates no significant differences

			N	P	Ca	Mg	K
				-------------------------(g kg^{-1})--------------------------			
Flowering	Floricanes	Canes	5.9 *	0.6 *	3.6	1.0	3.4 n
		Laterals	14.1 *	2.1 *	3.8	0.7	13.7 *
		Leaves	25.6 *	2.2 *	8.1	1.8	14.7 n
		Berrys	28.2 *	3.4 *	4.8	2.3	18.8 *
	Primocanes	Canes	16.5 n	2.0 n	2.8	1.5	13.8 n
		Leaves	31.6 n	3.3 n	7.1	2.6	19.8 n
Ripeness	Floricanes	Canes	4.2 *	0.3 *	3.1	0.8	2.8 n
		Laterals	12.0 *	1.8 *	4.7	1.3	11.4 *
		Leaves	21.6 *	1.7 *	11.8	3.9	11.6 n
		Berrys	17.0 *	2.1 *	4.9	2.4	14.1 *
	Primocanes	Canes	9.8 n	1.5 n	3.0	1.4	10.3 n
		Leaves	26.2 n	2.3 n	9.1	3.6	15.2 n
Dormancy	Primocanes	Cane	6.9	0.8	2.9	0.6	2.4

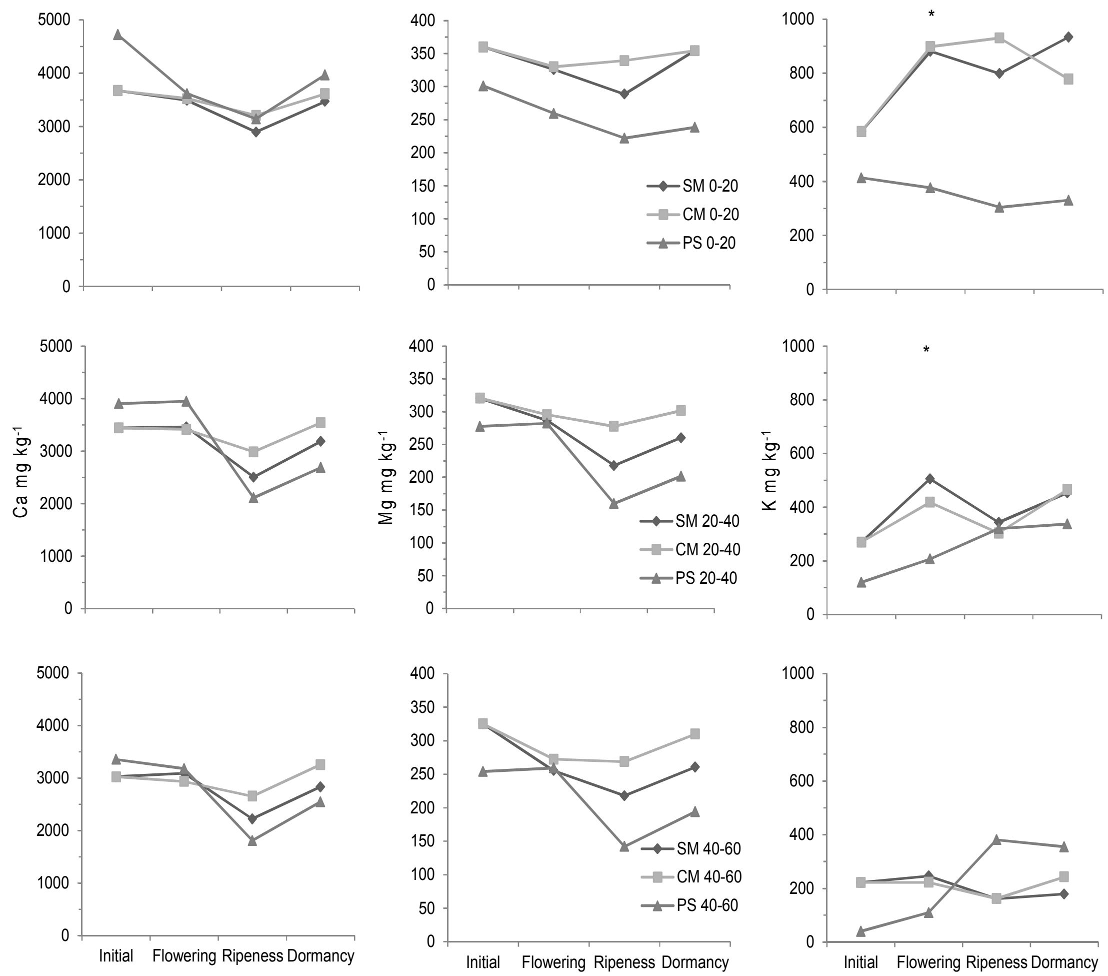


Fig. 1. Contents Ca, Mg and K extractable in soil at 0-20 cm, 20-40 cm and 40-60 cm depths during crop cycle. SM: suppression manure, CM: continuous manure application, PS: pristine soil. Asterisk indicate significant differences between SM, CM and PS treatments (P<0.05) for each sampling date

Table 4. Concentrations and amounts of nutrients in pruned material in CM. Dm: dry matter

Pruning	Dm	N	P	Ca	Mg	K
(g kg^{-1})	-	8.1	0.5	7.0	1.1	5.3
(Kg ha^{-1})	4006	32.5	2.2	28.0	4.4	21.2

Table 5. Concentration of nutrients in leaves in primocanes and floricanes (n=30) at flowering under suppression manure (SM) and continuous manure (CM) treatments. P: probability value of F. sd: standard deviation

Leaves	(g kg^{-1})	SM Average (sd)	CM Average (sd)	P
Primocane	N	28.6(0.17)	28.7(0.21)	0.95
	P	2.9(0.05)	2.9(0.02)	0.83
	K	22.2(1.34)	11.7(0.44)	0.26
floricane	N	25.5(0.10)	26.2(0.20)	0.60
	P	2.4(0.02)	2.3(0.04)	0.67
	K	18.6(0.93)	13.1(0.13)	0.36

No statistically significant differences between CM and SM were observed the vigor indices (number of lateral branches, length and diameters of the canes) (Table 6).

During the two years of evaluation, no statistically significant differences were found between CM and SM regarding berry yield (Fig. 4).

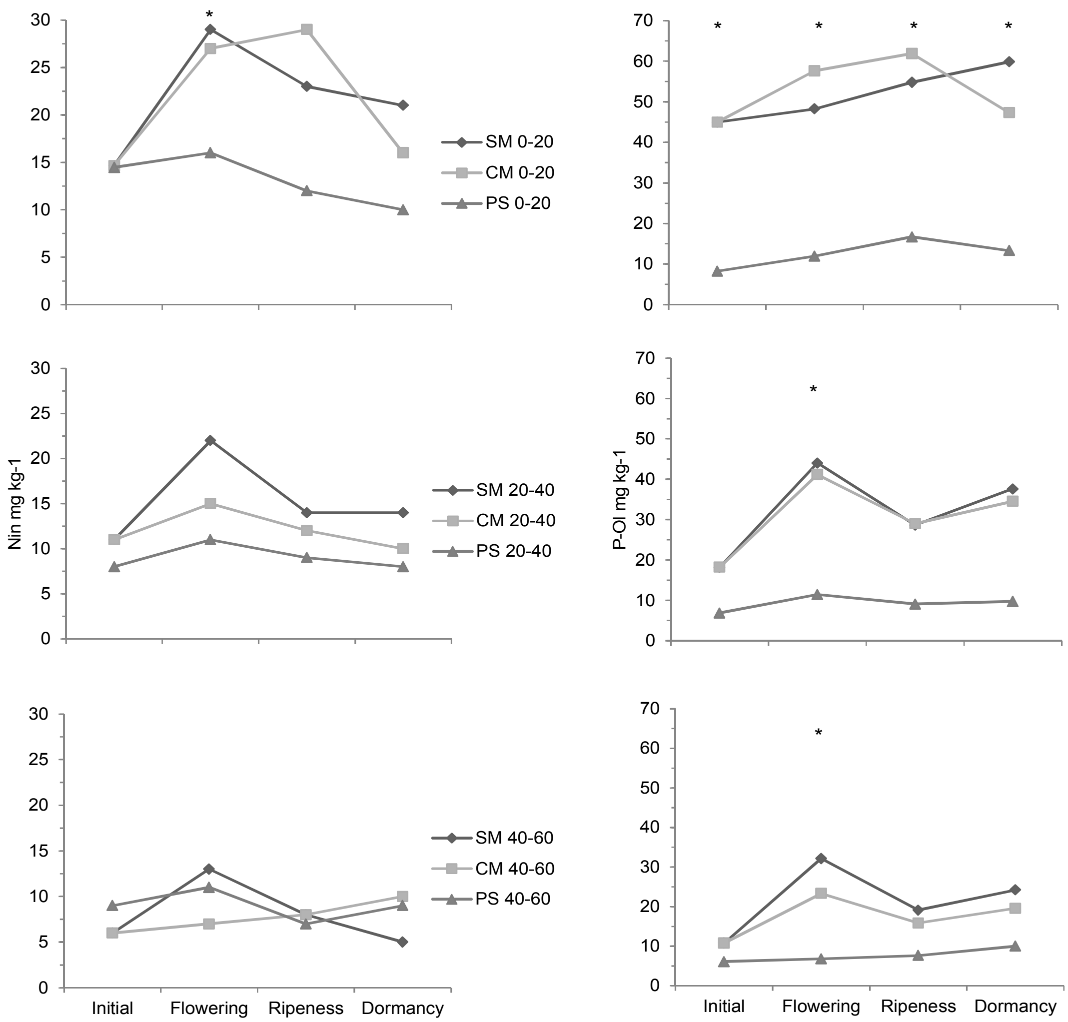
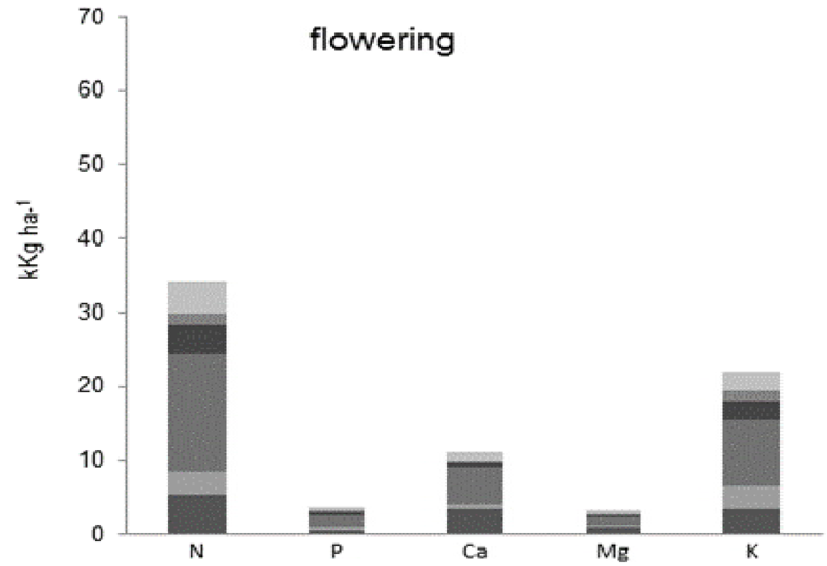


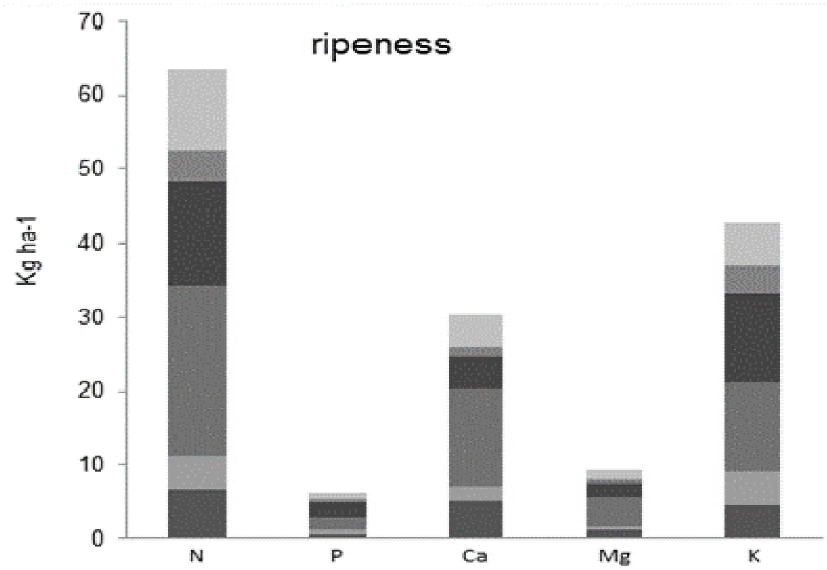
Fig. 2. Contents Nin (inorganic nitrogen) and P Olsen in soil at 0-20 cm, 20-40 cm and 40-60 cm depths during crop cycle. SM: suppression manure, CM: continuous manure application, PS: pristine soil. Asterisk indicate significant differences between SM, CM and PS treatments (P<0.05) for each sampling date

Table 6. Diameter at 50 cm, lenght and number of laterals branches in floricanes at the end of the 2008 growing season under suppression manure (SM) and continuous manure (CM) treatments. n = total number of units sampled in each treatment. P: probability value of F. sd: standard deviation

	SM			CM			P
	n	Average	(sd)	n	Average	(sd)	
number of laterals	128	14	(6)	111	13	(5)	0.06
lenght (cm)	128	171	(61)	111	169	(48)	0.73
diameter (cm)	128	0.86	(0.20)	111	0.92	(0.23)	0.07



	N	P	Ca	Mg	K
leaves (primocanes)	4,39	0,46	1,06	0,37	2,69
cane (primocanes)	1,54	0,19	0,22	0,13	1,26
berries (floricanes)	3,98	0,48	0,71	0,32	2,57
leaves (floricanes)	15,82	1,36	4,85	1,11	8,88
laterals (floricanes)	3,04	0,46	0,85	0,16	3,08
cane (floricanes)	5,44	0,60	3,29	0,99	3,47



	N	P	Ca	Mg	K
leaves (primocanes)	10,99	0,92	4,26	1,37	5,83
cane (primocanes)	3,98	0,56	1,41	0,48	3,72
berries (floricanes)	14,35	1,85	4,27	2,04	12,08
leaves (floricanes)	22,84	1,73	13,15	3,78	12,15
laterals (floricanes)	4,74	0,72	2,05	0,48	4,61
cane (floricanes)	6,61	0,55	5,13	1,23	4,38

Fig. 3. Quantities of nutrients accumulated in the aboveground biomass on raspberry crop during flowering and ripeness under continuous manure treatment

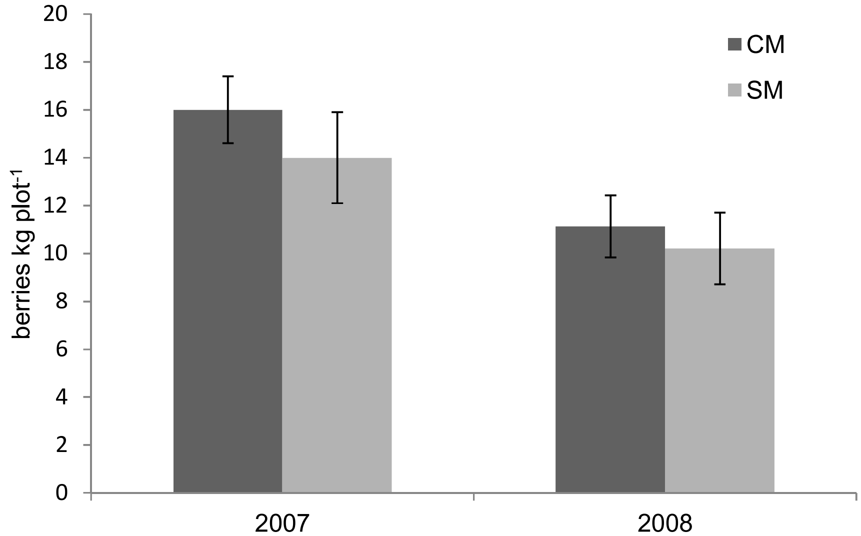


Fig. 4. Yield of berries under suppression manure (SM) and continuous manure (CM) treatments, Lines indicate SD

4. DISCUSSION

The manure caused a sharp increase in extractable K concentrations in the soil in comparison to PS (Fig. 1). However, extractable K concentrations in PS were already much higher than 126 mg kg^{-1}, a value considered as deficient according to [20,3].

The contents of extractable Ca and Mg in soils were high even for PS (Fig. 1). The presence of cypress trees (*Austrocedros chilensis*) in the open field (PS) might have influenced these results. This tree species produce a mulch rich in exchangeable Ca.

Saturation percentages at 0-20 cm of Ca and Mg (60% and 8%, respectively) were not so high because the CEC was high (28.5 $cmol_c$ kg^{-1}, Table 1). However, the soil is not considered deficient taking also into account the amount contributed by the manure (Table 2). Excess of Ca added by manures is not considered a limitation as Ca is an element that contributes to the formation of soil structure [21].

Both at flowering and at ripeness, in primocanes and floricanes, and under CM and SM (Tables 3 and 5), K concentration in leaves exceded the critical level of 7 g kg^{-1} for primocane leaves [3]. For N in leaves of primocanes, a critical level of 24 g kg^{-1} has been suggested [22]. Both primocane leaves at flowering and ripeness for CM (Table 3) and primocane leaves at 50 cm height for CM and SM (Table 5) showed data of N above this critical level.

Nutrient concentrations in the different plant organs (Table 3) were in agreement with [8] except for Ca, which was substantially lower in the present work, especially in leaves (both primocanes and floricanes). However, nutrient concentration in leaves should be taken with care because it is quite dynamic during the growing season and varies with leaf position on the cane [11]; also variations both within and between years compromise the effectiveness of the diagnostic approach [9]. In any case, the concentration of nutrients in leaves may suggest a posible deficiency, but the amounts of manure added should been couraged keeping in mind the concentrations of nutrients in other organs of the plant, dry matter production, fruit yield, and nutrient concentrations in manure and in soils. Nutrient management must be understood, planned and managed over periods longer than a single crop or growing season [23].

Each organ of the plant showed a characteristic nutrient concentration (Table 3) and a dilution Effect for N, P, K was observed from flowering to ripeness (Table 3). This has been extensively described in the literature for raspberry leaves [20,24] and other crops [25,26]. For example, there is abundant information about the dilution effect in N, additional N uptake per unit of additional biomass declines as a crop gets bigger [27]. Mechanisms by which this occurs (selfshading of leaves, change in leaf/shoot ratio during crop development, N remobilization towards growing organs) are clearly explained in [28]. In raspberry crops this may be very complex because vegetative growth continues through primocane growth simultaneously with reproductive growth in floricanes. Translocation of N from the cane to other parts of the plant has also been suggested [29].

The marked increase in the absorption of N, K, Ca from flowering to ripeness (Fig. 3) corresponded to the increase in the dry matter accumulated mainly in leaves (floricanes) and berries (floricane). The total amounts of nutrients extracted by the raspberry crop (Fig. 3) followed the same pattern (in order N > K > Ca > Mg > P) as that obtained by [8] (average of two raspberry varieties: 84, 65, 40, 11, 9 kg ha^{-1} for N, K, Ca, Mg and P respectively). Although values in the present work were slightly lower (64, 43, 30, 9, 6 kg ha^{-1} for N, K, Ca, Mg and P respectively). These data are very useful to determine the nutrient replenishment dose, which can be corrected taking into account the concentrations in plant organs, yields of berries, nutrient uptake efficiency and soil nutrient levels.

Significant amounts of nutrients were returned to the soil by pruning (Table 4) giving a positive nutrient balance. The dry matter of the pruning represents a very high percentage of dry matter of total aboveground biomass of the crop (over 80%). Incorporation of crop residues improves hydraulic and pore characteristics of soil [30] and increases microbial activity [31]. It would be very important, particularly in soils with low content of organic matter, to avoid pruning burning as a farming practice.

The absence of significant differences among CM and SM in vigor indices (Table 6) and fresh berries yields (Fig. 4) suggests that the dose of manure applied could be reduced. However, [29] reported low correlation between vigor indices (cane diameter and height, and lateral measurements) and fresh berry measurements. This author suggested that as berries ripened, the main change in their fresh weight and size was an accumulation of water (85 to 90% water in fresh berries); similar results were obtained in the present work. Then, soil parameter determinations should be used to confirm whether the dose manure applied is excessive. For example, a threshold value of 100 kg N ha^{-1} for nitrates content to 60 cm deph measured after berry's harvest has been suggested by [32] to avoid soil and water contamination. In this work, considering depth and soil bulk density (Table 1) and Nin concentrations (Fig. 2) values were 93 kg N ha-1 in SM and 85 kg N ha-1 in the CM, which suggests that the risk of contamination with nitrates is low.

The manure applied (CM and SM) caused a large increase of P-Ol level in soils up to 40 cm depth compared to PS,with values at 0-20 cm depth near and above 60 mg kg-1 P-Ol (Fig. 2), below 40 cm depth the increase of P-Ol was smaller. After one year of manure suppression, no changes in P-Ol levels were observed. The addition of manure had a positive effect for the crop initially, but may become a problem later since P is not easily removed from the soil. Around 60 mg kg^{-1} P-Ol in the plow-layer exceeds the requirements of most crops for optimal growth [33] and is a critical concentration (change-point) at which leaching starts for different soils [34,35]. These authors suggest this threshold after studying the relationship between the P-Ol (agronomic index) with extractable P in 0.01M $CaCl_2$ ratio1:5 soil: solution, which estimates the potential loss of soil P (environmental index). Although the soils under study have some influence of volcanic ash (Table 1) that could contribute to P retention, previous studies have shown that in these soils P-Ol values were highly correlated with P extractable in 0.01 M $CaCl_2$ values, demonstrating that the risk of movement of P is present [36].

The dairy manure used had three times more N than P (Table 2), but the raspberry N extraction of N was 10 times higher than that of P at ripeness (Fig 3), allowing that P accumulate in the soil with successive applications. This problema with the use of animal manures has been extensively reported in the literature [37, 38,39]. The ratio among P added through manuring (Table 2) and P extracted by the crop at ripeness (Fig. 3) was very high (4.7), while in the case of N, this ratio was closer (1.4). The application of P was 29.5 kg ha^{-1} per year (Table 2), rate that, in other crop such as rice could be considered low [40] or high for barley crop [38]. In this case manure has been applied each year, during which P has been applied systematically in excess, even considering a low uptake efficiency by the crop.

Another problem could also be that fertilizers and manures are used according to the relationship between the product prices (fruit or grain) and input prices (fertilizers or manures). When this ratio is high (or input like manure is easily obtained from complementary activities) and the yield is successful, manure is added in excess, a common problem in the soils of horticultural belts of cities, either with manures or inorganic fertilizers utilization. Intensive crops such as potato can result in excessive levels of P in soils when inorganic fertilizers are applied in high doses [41]. But when the relationship is low, less than necessary is added, as noted in large areas of grain crops with low and very low P levels in soils [42,43]. The economics must be taken into account, but in a context where the main assessment tool must be the nutrient balance of any particular crop.

Manures can be used from surplus to deficit areas, where a mechanism to facilitate the transport should be established [33]. Processing manure by drying, grinding and making pellets may expand the scale of utilization in natural pastures, cultivated pastures and grain crops as it can be applied with conventional machinery. Recycling nutrients and maintaining soil health must be a common objective for both organic and conventional agriculture.

At the end of the raspberry crop cycle, could be rotated with a highly extractive crop for example alfalfa which exports most of all aboveground dry matter produced. This would take advantage of the high levels achieved in soil fertility by the manure applied. In agrarian rural communities, the adoption of crop rotation practices with leguminous crops as well as environmental education and awareness on the adverse effects of excessive fertilizers application should be encouraged [44].

5. CONCLUSION

The nutritional status for nutrients studied for this raspberry crop, comparing with reference values, was optimal. The manure used was a very good source of nutrients. However, a reduction of the quantities of manure may be applied in the last years of raspberry crop production, taking into account also the threshold limit for N and P in soil.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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