Influence of Nitrogen Fertilization and Support Systems on Passion Fruit Yield and Economic Feasibility

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Summary. **A 2-year field study was conducted in two locations in the Dominican Republic to determine the influence of various support systems and nitrogen fertilization programs on passion fruit (*Passiflora edulis* var. *flavicarpa*) yield and economic returns. Three trellis systems were used: 1) single line, where a single wire was placed along the planting rows at 2 m high; 2) double lines, where two wires were established along the planting rows at 2 and 1 m high, respectively; and 3) crossed lines, with wires at 2 m high, allowing the vines to grow both along and across the planting rows. Nitrogen (N) fertilization rates were 13, 26, and 52 g/plant of N every 20 days. Plants trained with the single- and double-line support systems combined with 52 g/plant of N had higher marketable yield and had the lowest proportion of non-marketable fruit/plant per year. Partial budget analysis indicated that the single-line support system had a marginal return rate of 36% compared to the double-line support system.**

Passion fruit is native to the Brazilian Amazonia and is grown throughout South America, Central America, North America, and the Caribbean, as well as tropical and subtropical regions of Africa, Asia, and Australia (Ministerio de Agricultura y Ganadería, 2001; Morton, 1987; Sarmiento-Gómez, 1989). There are several passion fruit species and ecotypes dispersed around the world, including wild types, such as *P. incarnata*, which has been reported to grow as far north as Pennsylvania in the U.S. (Arjona et al., 1991). In 2002, Brazil, Ecuador, and Colombia were the leading producing countries in the world with 66%, 12%, and 11% of the planted surface area of passion fruit (Corporación Colombia Internacional, 2003). This fruit is highly appreciated for fresh consumption and industrial purposes, because of its diverse uses for juice, jelly, and ice cream products (Knight and Sauls, 1994; Santos, 2002; Sarmiento-Gómez, 1989).

A climacteric fruit, passion fruit is a vigorous perennial vine that is naturally supported by tendrils (Gamarra-Rojas and Medina, 1997; Knight and Sauls, 1994; Morton, 1987). However, in commercial fields, passion fruit is grown on trellis systems to prevent vines from growing on the ground. These trellises are supported by either trees or wood posts, connected with galvanized steel wires (Knight and Sauls, 1994). There are three typical trellis systems: 1) single line, 2) double lines, and 3) crossed lines. The single- and double-line systems use one and two wires that are oriented in the same direction as the planting rows, whereas the crossed-line system ties a single wire on top of each post, in a grid-like structure across planting rows. Little research has been conducted comparing these support systems.

Adequate N fertilization is critical to improve passion fruit number and quality. Santos (2002) showed that N application frequency and rates had a significant effect on yield. At the same time, excessive amounts of N can produce extremely vigorous foliage at the expense of flowering, which could increase vegetative weight and stress on the support system, reduce yields, and elevate costs (Morton, 1987). There are no reports on the combined effect of trellis system and N fertilization rates on production and profitability. Therefore, the objective of this study was to determine the influence of various support systems and N fertilization rates on passion fruit yield and economic returns in two production zones in the Dominican Republic.

Materials and methods

Field trials were conducted during 1998 and 1999 in two locations in the Dominican Republic. These experimental sites were located in grower fields in Monte Plata and San José de Ocoa. Monte Plata is located between 60 and 100 m above sea level with average temperature of 25 °C and 2200 mm/year rainfall, whereas San José de Ocoa is between 500 and 600 m above sea level, with average temperature of 23 °C and 1500 mm/year rainfall. The predominant soils in Monte Plata are ultisols with pH 6.3, while in San José de Ocoa they are mollisols with pH 6.9.

Prior to field transplanting, seeds of 'Criolla amarilla' yellow passion fruit were extracted from marketable fruit collected from a 3-year-old adjacent commercial field. Three weeks after seed collection, seeds were planted in 0.5-L polyethylene bags filled with a commercial potting mix and placed in a 40%-light saran house. When seedling vines reached 0.40 m long (40 to 50 d after planting), seedlings were transplanted in single rows in the selected experimental sites. Each planting hole was 0.25 m deep by 0.15 m in diameter. Single rows were 2.5 m apart with 2.5 m between-plant spacing (1600 plants/ha). Establishment fertilization, pest control, and crop management were accomplished following current grower practices for each production zone.

Two months before transplanting, support systems were built using 2.5-

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
2.5400	inch(es)	cm	0.3937
25.4000	inch(es)	mm	0.0394
28.3495	oz	g	0.0353
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

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m-long × 0.15-m-diameter wooden posts. Each post was driven 0.5 m into the soil and a single post was buried equidistant from each two passion fruit plants. The trellises were built with No. 8 galvanized steel wires in three different arrangements: 1) single line, where a single wire was placed along the planting rows on top of each post at 2 m high; 2) double lines, where two wires were established along the planting rows at 2 and 1 m high, respectively; and 3) crossed lines, with wires at the top of each post, allowing the vines to grow both along and across the planting rows. In the double-line system, the lower wire was set on each post by driving two 5-cm-long screws into each post for supporting plant weight.

Beginning at 4 weeks after transplanting, each passion fruit plant was fertilized either with 13, 26, or 52 g/plant of N every 20 d for 2 years, using urea as the fertilizer source. Granular urea was applied to the soil at 20 cm from the stem of each plant and immediately covered with soil. Other plant nutrients were supplied according to soil nutrient analysis for each location. Treatments were arranged in a split-plot design with four replications, where support systems were the main plots. Experimental units had 20 passion fruit plants each. Passion fruit vines were allowed to grow during 2 years prior to treatment establishment, following commercial growing practices for each location, except for N fertilization.

Passion fruit were collected during two seasons (Spring 1998–Fall 1998 and Spring 1999–Fall 1999) and classified as marketable (fruit ≥20-mm diameter), and non-marketable (fruit <20-mm diameter or damaged) fruit number per plant, according to local market standards. Partitioning of non-marketable fruit number per plant was calculated as a percentage of total fruit number per plant, and resulting data were transformed prior to analysis of variance (ANOVA) with square root arc sine to normalize the treatment values. Data from each season were examined with ANOVA ($P = 0.05$). Treatment means were separated with standard errors (SAS Institute, Cary, N.C.).

For the economic analysis, marginal return rates (MRR) were calculated, applying the partial budget methodology on the two most promising treatments for the first production season (Centro Internacional para el Mejoramiento de Maíz y Trigo, 1988). This methodology uses only the variable production costs that change between the two treatments to be compared. Thus, other production costs were assumed to be constant and a whole-farm operation budget was not necessary. The marginal return rate is calculated dividing the highest net income by the lowest net income, and indicates the percentage of net revenue gains of switching from one treatment to another.

Results and discussion

There was no significant treatment by location interaction for all variables. Therefore, data results from two locations were combined for analysis. There was significant support system and N fertilization interaction for total, marketable, and non-marketable passion fruit number per plant. For total fruit number per plant, there were no significant differences among the three support systems with the highest N level, producing an average of 88 fruit/plant per year (data not shown).

As N rate increased, there was a tendency to increase marketable fruit number per plant regardless of the support system. Within the lowest N rate, the single-line support system had the highest annual yield (37 fruit/plant) in comparison with the other two support systems, representing an increase of approximately 50% in marketable fruit number (Table 1). With 26 g/plant of N, there was no marketable yield difference between the single- and double-line support systems, which produced 45 and 40 fruit/plant per year, respectively. However, the single-line support system had about 36% higher yield than the crossed-line system with 26 g/plant of N (Table 1). Increasing N rates to 52 g/plant resulted in higher yields than with the intermediate N rate within each support system. At this N rate, there was no difference between the single- and double-line support systems, with 77 and 85 fruit/plant per year, respectively, which in turn outperformed the crossed-line support system, producing an average of 28% and 42% more marketable fruit.

When examining across N rates, the yield values for the combination of 26 g/plant of N and either the single- or double-line support systems were equal to those obtained with the combination of a single-line system and 13 g/plant of N. These two support systems nearly doubled passion fruit production as N rate increased from 26 to 52 g/plant (Table 1).

Yield partitioning to non-marketable fruit fluctuated depending on both support system and N rate (Table 1). For instance, non-marketable fruit with the single-line support system ranged between 8% and 20% of the total fruit production. However, a wider partitioning range was found with double-lines (7% to 58%). With the crossed-line support system, the percentage of non-marketable fruit increased (29% to 61%) as N rate decreased. Within the highest N rate, the lowest non-marketable fruit percentages were found with either the single- or double-line support systems.

The results indicate that passion fruit yield can be improved with ap-

Table 1. Effects of support systems and nitrogen (N) fertilization rates on marketable and non-marketable passion fruit grown in 1998 and 1999 at Monte Plata and San José de Ocoa, Dominican Republic.

Support system[y]	N rate (g/plant)[x]	Marketable fruit[z] (no./plant/year)	Non-marketable fruit[z] (no./plant/year)	Non-marketable fruit[z] (%)
Single line	13	37 ± 4	3 ± 0.6	8 ± 2.8
	26	45 ± 5	11 ± 2.2	20 ± 4.3
	52	77 ± 9	11 ± 3.1	13 ± 3.6
Double lines	13	18 ± 5	25 ± 3.6	58 ± 4.0
	26	40 ± 9	25 ± 2.7	39 ± 3.9
	52	85 ± 4	6 ± 1.1	7 ± 4.1
Crossed lines	13	15 ± 5	23 ± 3.7	61 ± 4.7
	26	29 ± 6	23 ± 1.9	44 ± 3.7
	52	60 ± 9	25 ± 1.3	29 ± 2.9

[z]Treatment means for marketable and non-marketable fruit number and percentage of total fruit number ±SE.
[y]No significant location × treatment interaction ($P > 0.05$). There was significant ($P < 0.05$) support system × N rate interaction for fruit categories.
[x]1 g = 0.0353 oz.

Table 2. Comparison of partial budgets and marginal return rate (MRR) of combinations of support systems and nitrogen (N) fertilization rates in passion fruit production during the first season (1998) at Monte Plata and San José de Ocoa, Dominican Republic.

Cost components[z]	Single-line system with 52 g/plant of N[y]	Double-line system with 52 g/plant of N
	Marketable yield	
Fruit production (no./ha/year)	123,200	136,000
Total gross revenue ($/ha)	2536.47	2800.00
	Variable costs	
Posts and wires ($/ha)	840.00	1486.23
Maintenance hand labor ($/ha)	55.00	100.00
Fruit picking and packing ($/ha)	18.48	20.40
Total variable costs ($/ha)	913.48	1606.63
	Revenues	
Net income ($/ha)	1622.99	1193.37
MRR (%)	36	

[z]Total annual gross revenue = fruit production multiplied by unit price ($0.0206/unit), net income = total gross revenue minus total variable costs, MRR = [(highest net income/lowest net income) – 1] × 100; 1 fruit/ha = 0.4047 fruit/acre, $1/ha = $0.4047/acre.
[y]1 g = 0.0353 oz.

plications of 52 g/plant of N every 20 d with either the single- or double-line support system. From an economical standpoint, the comparison between these two treatments during the first season in both locations resulted in the single-line support system having a MRR rate of approximately 36% in comparison with the double-line support system. For instance, within the N rate of 52 g/plant, for each dollar of net profit obtained with the double-wire support system, passion fruit growers with the single-wire system would instead have a net gain of $1.36. These results showed that at the highest N rate, adding an extra support wire to passion fruit rows does not significantly improve passion fruit yield, and it reduced net revenues.

Literature cited

Arjona, H.E., F.B. Matta, and J.O. Garner, Jr. 1991. Growth and composition of passion fruit (*Passiflora edulis*) and maypop (*P. incarnata*). HortScience 26:921–923.

Centro Internacional para el Mejoramiento de Maíz y Trigo. 1988. From agronomic data to farmer recommendations: An economics workbook. CIMMYT, Mexico City.

Corporación Colombia Internacional. 2003. Perfil de producto: Maracuyá. Inteligencia de Mercados, No. 19. Corporación Colombia Internacional, Bogotá, Colombia.

Gamarra-Rojas, G. and M. Medina. 1997. Growth of the yellow passion fruit. Fruits 52:19–26.

Knight, Jr., R.J. and J.W. Sauls. 1994. The passion fruit. Fact Sheet HS-60. IFAS Publ., Univ. of Florida, Gainesville.

Ministerio de Agricultura y Ganadería. 2001. Identificación de mercados y tecnología para productos agrícolas tradicionales de exportación: Maracuyá. Ministerio de Agricultura y Ganadería, Quito, Ecuador.

Morton, J. 1987. Passion fruit, p. 320–328. In: C.F. Dowling (ed.). Fruits of warm climates. Florida Fair Books, Boynton Beach, Fla.

Santos, B.M. 2002. Influencia de la fertilización nitrogenada en la interferencia de *Digitaria sanguinalis* sobre maracayá. Manejo Integrado de Plagas y Agroecología 64:72–76.

Sarmiento-Gómez, E. 1989. Frutas en Colombia. Ediciones Cultural Colombiana, Bogotá, Colombia.