Training System and Rootstock Affect Yield, Fruit Size, Fruit Quality and Crop Value of Sweet Cherry

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Abstract

A 1999 field trial compared 'Hedelfingen', 'Lapins', and 'Sweetheart' cherry cultivars on Gisela 5, (Gi.5), Gisela 6, (Gi.6) and MxM.2 rootstocks each planted in six cherry training systems (Central Leader-336 trees/ha, Spanish Bush-673 trees/ha, Slender Spindle-897 trees/ha, V-997 trees/ha, Marchant-1,035 trees/ha, and Vertical Axis-1,196 trees/ha). A second 2002 trial compared 'Lapins' and 'Regina' cultivars on Gi.5, Gi.6, Gi.12 and Mazzard seedling rootstocks each planted in four cherry training systems (Quad Axis-598 trees/ha, Spanish Bush-748 trees/ha, Central Leader-748 trees/ha, and Vertical Axis-997 trees/ha). After 11 years tree size in experiment 1 was smallest with Gi.5, intermediate with Gi.6 and largest with MXM.2. In experiment 2 after 8 years, trees on Gi.5 were the smallest, followed by trees on Gi.6, G.12 and Mazzard which were the largest. Trees on all three Gisela stocks were much more precocious than either MXM2 or Mazzard. Cumulative yield after 11 years with experiment 1 or after 8 years with experiment 2 were highest for trees on Gi.5 followed by Gi.12, Gi.6, Mazzard and MXM.2. With the self fertile cultivars, 'Sweetheart' and 'Lapins', Gi.5 induced excessive production which resulted in small fruit size. However, with the self infertile cultivar, 'Regina', Gi.5 was the only rootstock which induced commercially acceptable high yields of large fruit. Although Gi.12 was a vigorous tree, it had much greater precocity and productivity than Mazzard. Average fruit size was largest on Gi.12 and Gi.6, intermediate on MXM.2 or Mazzard and smallest on Gi.5. Among training systems, the Vertical Axis system had the highest cumulative yield per hectare followed by the V, the Slender Spindle, the Spanish Bush, the Quad Axis, the Marchant, and the Central Leader. Cumulative yields largely reflected density. Fruit size was largest with the Central Leader, Quad Axis and Spanish Bush, intermediate with the Slender Spindle and Marchant system and smallest with the V and the Vertical Axis. Fruit soluble solids were highest with the Central Leader and Quad Axis and lowest with the Spanish Bush and the Marchant. Cumulative crop value was highest for the V in experiment 1 and for the Vertical Axis in experiment 2.

INTRODUCTION

Dwarfing cherry rootstocks have allowed new possibilities for developing high-density sweet cherry (*Prunus avium* L.) orchards with smaller trees that are more precocious and productive and can either be covered with rain exclusion shelters or high tunnels to prevent rain cracking (Lang, 2005; Robinson et al., 2004). Several high density training systems have been developed for sweet cherries (Balmer, 2001; Long, 2001a; Weber, 2001; Zahn, 1994), giving fruit growers many options for choosing a planting density, rootstock and training protocol. The objective of this project was to compare high-density production systems on both standard and dwarfing rootstocks for both self fertile and self infertile sweet cherries and determine the effect of training system and rootstock on yield, fruit size, fruit quality and crop value.

MATERIALS AND METHODS

In April 1999, a replicated field trial was planted at Geneva, New York with 'Hedelfingen' on Gisela 5 (Gi.5), Gi.6 and MxM.2; and 'Lapins' and 'Sweetheart' on Gi.5 and Gi.6. Each variety/rootstock combination was planted in six training systems: Central Leader-336 trees/ha, Spanish Bush-673 trees/ha, Slender Spindle-897 trees/ha, V-system-997 trees/ha, Marchant inclined tree-1035 trees/ha and Vertical Axis-1196 trees/ha. The training recipes for each system and the plot design were published earlier (Robinson et al., 2004).

A second trial was planted in May 2002, at Geneva, New York with 'Lapins' and 'Regina' on Gi.5, Gi.6, Gi.12 and Mazzard seedling rootstocks. Each variety/rootstock combination was planted in four training systems: Quad Axis-598 trees/ha, Spanish Bush-748 trees/ha, Slender Spindle-748 trees/ha, and Vertical Axis-997 trees/ha.

Experimental design of both experiments was a randomized complete block with a split-split plot and 3 replications. The main plot was training system, the sub-plot was cultivar and the sub-subplot was rootstock. Each sub-subplot was a 10m row section of 3-8 trees depending on the spacing for the system.

With both experiments, yield and fruit size data were recorded each year and trunk circumference at the end of the experiment. A 50 fruit sample was collected each year from each sub-subplot and analyzed for fruit size, soluble solids and proportion of cracked fruit. A fruit packout was calculated from the percentage of the sample in each fruit size class. Economic crop value was calculated by first subtracting yield of cracked fruit from total yield and then calculating yield of each fruit size class and multiplying by prices for each size class. Data were analyzed by analysis of variance and then by regression to determine the effect of tree density. In experiment 1, the design was unbalanced with 'Hedelfingen' planted on three rootstocks, while 'Lapins' and 'Sweetheart' were planted on two rootstocks thus each cultivar was analyzed separately. In the experiment 2 both cultivars were analyzed together since the design was balanced.

RESULTS

Tree Survival and Size

In both experiments, tree survival was better with the Gisela rootstocks than with the seedling control (MXM2 or Mazzard) (Table 1). There was also a significant rootstock effect on tree size, as measured by trunk cross-sectional area (TCA) in both experiments. In experiment 1, 'Hedelfingen' trees on Gi.5 were significantly smaller (30%) than trees on Gi.6, which in turn were about 20% smaller than trees on MxM.2 (Table. 1). With 'Lapins' and 'Sweetheart' there was no difference in TCA between Gi.5 and Gi.6. In the second trial, trees of both 'Lapins' and 'Regina' on Gi.5 were smallest followed in order by trees on Gi.6, Gi.12 and Mazzard which were the largest (Table 2).

Planting system also had a significant effect on final TCA. The Central Leader trees (lowest planting density) were the largest and the Marchant and Vertical Axis (highest planting density) trees were the smallest. There was a significant negative linear relationship between tree planting density and tree size with each of the 3 rootstocks (Fig. 1). Trees planted at the highest density were about 60% as large as those at the lowest density. The greatest effect of planting density on tree size was with MXM2 rootstock. In the second trial, there was also a negative linear relationship of planting density and TCA for each of the 4 rootstocks (Fig. 2). Gi.5 was the least responsive rootstock to tree density effects on tree size.

Yield

In the first trial, 'Hedelfingen' trees on Gi.5 had the greatest cumulative yield per ha while Gi.6 was intermediate and MxM.2 had the lowest yield (Table 1). Cumulative yield of MxM.2 was extremely low compared to the Gisela rootstocks. Annual yields varied significantly depending on winter bud survival and fruit set percentage in the spring (Fig 1). In the winter preceding the 2004 season, low temperatures killed most of the flower buds in this trial. Among varieties, 'Sweetheart' had the most flower buds killed followed by 'Lapins' and 'Hedelfingen', while 'Regina' had the highest flower bud survival. With 'Lapins' and 'Sweetheart', there was no difference in cumulative yield between Gi.5 and G.6 (Table 1).

In the second trial, both 'Lapins' and 'Regina' trees on either Gi.5, 6 or 12 had much greater cumulative yield per ha than Mazzard which had very low yields (Table 2). All three Gisela stocks had similar yields with 'Lapins' but with 'Regina' Gi.5 had significantly greater cumulative yield. Annual yields varied less than in experiment 1 (Fig. 2). Lapins had greater cumulative yield than 'Regina'.

In experiment 1, the Vertical Axis system had the highest cumulative yield per ha regardless of rootstock followed by the V, the Slender Spindle, the Marchant, the Spanish Bush, and the Central Leader systems (Fig. 1). The combination of Vertical Axis training and Gi.5 rootstock resulted in very high 11-year cumulative yields of 110 t/ha for 'Hedelfingen', 120 t/ha for 'Lapins' and 113 t/ha for 'Sweetheart'. In contrast, the Vertical Axis system with the full vigor MxM.2 rootstock had a cumulative yield of only 38 t/ha with 'Hedelfingen'. In the second experiment, the Vertical Axis had the highest yield regardless of rootstock followed by the Slender Spindle, Spanish Bush and Quad Axis (Fig. 2). The Slender Spindle and the Spanish Bush were planted at the same density but the Slender Spindle had slightly higher yield with each rootstock except Gi.6.

The differences in yield between systems in both experiments were largely a function of tree density but also interacted with rootstock(Figs. 1 and 2). There was a positive linear relationship of tree planting density and cumulative yield/ha for each rootstock with the greatest slopes with Gi.5 and Gi.12, intermediate slopes with Gi.6 and the smallest slope with MXM2 and Mazzard. The slopes of the lines for the 3 rootstocks in the first experiment indicated that each additional tree planted per ha resulted in 21-63 kg over 11 years of additional cumulative yield. The slopes of the lines of the 4 rootstocks in the second experiment indicated that each additional tree planted per ha resulted in 40-90 kg over 8 years of additional yield. In the first experiment, the Marchant system was consistently below the regression line indicating that it had significantly lower cumulative yield than expected from its tree density.

Yield Efficiency

There was a large effect of rootstock on yield efficiency (Tables 1 and 2). In the first experiment, 'Hedelfingen' trees on Gi.5 were 5 times as efficient as trees on MxM.2 and twice as efficient as on Gi.6. With 'Lapins' and 'Sweetheart' there were no differences in yield efficiency between Gi.5 and 6. In the second experiment, Gi.5 and 6 had similar yield efficiency with 'Lapins' but with 'Regina', Gi.5 was much more efficient than Gi.6. Gi.12 had intermediate efficiency while Mazzard had low efficiency.

Among training systems, the Vertical Axis system was more efficient than any other system while the Central Leader and the Quad Axis systems had the lowest cumulative yield efficiency (Figs. 1 and 2). There was a significant positive linear relationship between tree density and cumulative yield efficiency. However, the Marchant trellis was significantly less efficient than predicted by the regression equation. The yield efficiencies of both Mazzard and MXM2 were relatively insensitive to increasing tree density while the yield efficiencies of Gi.5 and Gi.6 were affected more by tree density.

Fruit Size and Quality

In experiment 1 with 'Hedelfingen', the largest fruit size averaged over the 9 cropping seasons was with Gi.6, followed by MxM 2 and Gi.5 which had the smallest fruit size. However, with 'Lapins' Gi.5 had larger size than Gi.6 and with 'Sweetheart', there was no difference in fruit size between Gi.5 and Gi.6. In the second experiment with both 'Lapins', Gi.12 had the largest fruit size followed by Mazzard, Gi.6 and Gi.5 which had the smallest fruit size. With 'Regina', Gi.12 had the largest fruit size. Gi.5, Gi.6 and Mazzard all had similar fruit size but smaller than Gi.12.

Among training systems, average fruit size in the first experiment was not affected by system when on Gi.5 or Gi.6 but with MXM 2 fruit size of the Central Leader system was largest followed by the Slender Spindle, Spanish Bush, Marchant, V and the Vertical Axis systems. Fruit size was negatively correlated with planting density for MXM 2 rootstock but not with Gi.5 or 6 (Fig. 1). In the second experiment, the Quad Axis system had the largest fruit size followed by the Slender Spindle, the Spanish Bush and the Vertical Axis which had the smallest fruit size. Fruit size was negatively correlated with planting density for the 3 Gisela rootstocks in the second experiment but not with Mazzard (Fig. 2).

Fruit soluble solids in the first experiment with 'Hedelfingen', was highest with Gi.6 followed by MxM.2 and Gi.5 which had the lowest soluble solids (Table1). With 'Lapins', Gi.5 had higher average soluble solids than Gi.6 while with 'Sweetheart', there were no significant differences in soluble solids content between Gi.5 and Gi.6. In the second experiment with both 'Lapins', there were no differences in fruit soluble solids between the rootstocks but with 'Regina', Gi.5 had the highest soluble solids followed by Gi.6, Gi.12 and Mazzard which had significantly lower soluble solids than any of the Gisela stocks (Table 2).

Among systems, fruit soluble solids was highest with the Central Leader and lowest with the Spanish Bush (data not shown). In the second experiment, soluble solids was highest with the Quad Axis and lowest with the Spanish Bush (data not shown) Fruit soluble solids was not related to tree planting density in either experiment.

Crop Value

In experiment 1, cumulative crop value was greatest for trees on Gi.6, followed by Gi.5 and MxM.2 which had half the cumulative crop value as the Gisela stocks (Table 1). With 'Lapins', and 'Sweetheart', there was no difference in cumulative crop value between Gi.5 and Gi.6. In the second experiment, trees on Gi.12 had the greatest crop value with 'Lapins' followed by trees Gi.5 and 6 and Mazzard (Table 2). With 'Regina', Gi.5 had the greatest crop value followed by Gi.12, Gi.6 and Mazzard. With both cultivars trees on Mazzard had half the cumulative crop value of trees on either of the Gisela rootstocks.

Among systems in the first experiment, cumulative crop value was greatest for the Vertical Axis when planted on Gi.5 or MXM 2 but with Gi.6 the V system had the highest crop value (Fig. 1). The Central Leader had the lowest crop value with Gi.5 and Gi.6 but with MXM 2 rootstock the Marchant had the lowest cumulative crop value. The difference between the top and bottom systems was three fold. In the second experiment, the Vertical Axis had the highest cumulative crop value regardless of rootstock, followed by the Slender Spindle, Spanish Bush and the Quad Axis (Fig. 2).

The differences in crop value between systems in both experiments were largely a function of tree density but also interacted with rootstock (Figs. 1 and 2). There was a positive linear relationship of tree planting density and cumulative crop value for each rootstock with the greatest slopes with Gi.5, Gi.6 and Gi.12, and the smallest slope with MXM2 and Mazzard. The slopes of the lines for the 3 rootstocks in the first experiment indicated that each additional tree planted per ha resulted in $ 13-42 over 11 years of additional crop value. The slopes of the lines of the 4 rootstocks in the second experiment indicated that each additional tree planted per ha resulted in $ 52-74 over 8 years of additional crop value. In the first experiment, the Marchant system was consistently below the regression line indicating that it had significantly lower cumulative crop value than expected from its tree density.

DISCUSSION

Our results after 11 or 8 years, show the strong positive relationship of tree densities and cumulative yields. The level of cumulative yield with the high density plantings was 2-3 times the level of low density plantings. This is similar to the results of planting density studies with apple (Robinson, 2003). With our cherry data, the relationship appears to be linear over the densities we considered, whereas with apple, the relationship is curvilinear. It is likely, that over a broader range, the relationship would be curvilinear with cherry.

There were some differences among systems that were not explained by planting density. The Marchant system consistently had lower yields, yield efficiency and crop value than expected from its planting density which indicates that this system is not a good system for sweet cherry. Secondly, the Spanish Bush system gave lower yield and lower soluble solids than the Slender Spindle when planted at the same density. The lower yield is likely due to the short tree stature of the Spanish Bush while the lower soluble solids is likely due to the heavy internal canopy shading of the Bush shaped trees.

Our results, also illustrate, the value of the precocious Gisela rootstocks for early and mature production (Balmer, 2001; Perry et al., 1996; Robinson et al., 2004; Weber, 2001). Gi.5 was the most productive and efficient stock in our studies but had the smallest fruit size. The Gi.5 trees had such large crops that fruit size and soluble solids were both lower than the Gi.6 trees, indicating that the Gi.5 trees were over-cropped and that resources were limiting for fruit development. The successful commercialization of Gi.5 will require modified pruning strategies (Andersen et al., 1999; Claverie and Lauri, 2005; Lang, 2005; Reginato et al., 2008) or thinning (Whiting et al., 2006). An exception to this problem is 'Regina' on Gi.5, which was the only combination to achieve high commercial yields. The Gi.6 rootstock was slightly less productive and less efficient than Gi.5 but had better fruit size which combined to result in very similar cumulative crop value as Gi.5 after 11 years. The Gi.6 trees had larger fruit size and higher fruit soluble solids than even the standard sized trees on MxM.2, indicating that they have not over-cropped. Gi.12 is a more vigorous stock than either Gi.5 or 6 but was just as productive and had large fruit size. With 'Lapins', it had the best crop value. This rootstock is newer than Gi.5 or 6 but appears to have outstanding potential for medium density orchards of 700-800 trees/ha. MxM.2 and Mazzard were very unproductive and vigorous in our studies and not suited to high density plantings.

Another important result, is that tree size (as measured by TCA) can be reduced with increasing tree density. This is important since it means high tree densities will be manageable in the smaller allotted space per tree for a greater period of time. This reduction in tree size, associated with planting density, was likely due to greater root-to-root competition in the high density systems, the removal of all large branches in the high density systems and the heavier crops of the high density systems. A negative effect of high planting densities may be slightly smaller fruit size.

Considering both yield and fruit size, cumulative crop value of the Vertical Axis, Slender Spindle and the V system were the three best systems in these trials. The Slender Spindle and the V systems combined relatively high yields with good fruit size and quality. The Vertical Axis system was extremely productive, but had slightly smaller fruit size. The large fruit size and the high soluble solids content with the Slender Spindle and the V systems indicate that these were not over-cropped, whereas the smaller fruit size and lower sugar content of the Vertical Axis trees indicates this system was slightly over-cropped. To make the Vertical Axis system perform better will require modified pruning strategies such as annual heading of one-year-old lateral shoots to reduce the cropping potential of the system (Lang, 2005).

CONCLUSIONS

There is a strong relationship between tree density and yield or crop value. Tree density is more important than planting system.

Trees on Gi.5 are about 60-65% the size of trees on seedling rootstocks and should be planted at densities from 1,000-2,000 trees/ha. Trees on Gisela 5 are 2-3 times as productive as trees on seedling stocks but aggressive crop load management is required with many cultivars to achieve satisfactory fruit size. With low cropping cultivars like 'Regina', Gisela 5 gives much better yield than other stocks with good fruit size.

Trees on Gi.6 are about 70-80% the size of trees on seedling rootstock and should be planted at densities from 750-1,200 trees/ha. Trees on Gisela 6 are 2-2.5 times as productive as trees on seedling stocks. Fruit size with most cultivars on Gi.6 is as good as Mazzard or MXM2.

Trees on Gi.12 are about 80-90% the size of trees on seedling rootstock and should be planted at densities from 750-1,200 trees/acre. Trees on Gisela 12 are 2.5 times as productive as trees on seedling stocks. Fruit size is better than Mazzard.

Systems that use minimal pruning during the early years have high early yields (Vertical Axis, Slender Spindle, V) while training systems that rely on extensive pruning during the first 4 years have lower yields (Spanish Bush, Central Leader, Marchant Trellis and Quad Axis).

Literature Cited

Andersen, R.L., Robinson, T.L. and Lang, G.A. 1999. Managing the Gisela cherry rootstocks. New York Fruit Quarterly 7(4):19-22.

Balmer, M. 2001. Sweet cherry tree densities and tree training. Compact Fruit Tree. 34(3):75-77.

Claverie, J. and Lauri, P.E. 2005. Extinction training of sweet cherries in France-Appraisal after six years. Acta Hort. 667:367-371.

Lang, G.A. 2005. Underlying principles of high density sweet cherry production. Acta Hort. 667:325-335.

Long, L. 2001. Cherry training systems: Selection and development. Pacific Northwest Extension Publication #543. Oregon State University. Corvallis, Oregon.

Perry, R., Lang, G., Andersen, R., Anderson, L., Azarenko, A., Facteau, T., Ferree, D., Gaus, A., Kappel, F., Morrison, F., Rom, C., Roper, T., Southwick, S., Tehrani, G. and Walsh, C. 1996. Performance of the NC-140 cherry rootstock trials in North America. Compact Fruit Tree 29:37-56.

Reginato, G.H., Robinson, T.L. and Yoon, T.M. 2008. Improving cherry fruit size of self-fertile cultivars in NY orchards. NY Fruit Quarterly 16(3):28-31.

Robinson, T.L. 2003. Apple orchard systems. In: D.C. Ferree and I.J. Warrington (eds.), Apples: Physiology, production and uses. CABI Publishing. Wallingford, Oxon, United Kingdom.

Robinson, T.L., Andersen, R.L. and Hoying S.A. 2004. Performance of Gisela cherry rootstocks in the Northeastern United States. Acta Hort. 658:231-240.

Weber, M.S. 2001. Sweet cherry orchard management with dwarfing rootstocks. Compact Fruit Tree 34(1):20-22.

Whiting, M.D., Ophardt, D. and McFerson, J.R. 2006. Chemical blossom thinners vary in their effect on sweet cherry fruit set, yield fruit quality, and crop value. HortTechnology 16(1):66-70.

Zahn, F.G. 1994. Höhengerechter Pflanzabstand durch Stärkenbezogene Baumbehandlung. Erwerbsobstbau 8:213-220.

Tables

Table 1. Performance of Gisela 5, Gisela 6 and MXM 2 cherry rootstocks with ‘Hedelfingen’, ‘Lapins’ and ‘Sweetheart’ cherry cultivars over 11 years at Geneva, NY.

Cultivar	Rootstock	Tree survival (%)	Trunk cross-sectional area (cm^2)	Cum. yield (t/ha)	Cum. yield efficiency (kg/cm^2 TCA)	Average fruit size (g)	Average soluble solids (%)	Cum. crop value ($/ha)
‘Hedelfingen’	Gi5	100	152.4	73.6	0.56	6.95	15.3	49,036
	Gi6	100	208.1	44.1	0.25	8.73	17.5	52,884
	MXM2	92	256.8	20.9	0.10	8.24	16.9	21,001
LSD ‘Hedelfingen’ $P \leq 0.05$		8	18.3	8.0	0.06	0.25	0.34	12,006
‘Lapins’	Gi5	100	197.3	92.3	0.58	8.4	16.1	74,530
	Gi6	100	199.7	97.1	0.60	8.19	15.7	71,733
LSD ‘Lapins’ $P \leq 0.05$		-	15.5	6.7	0.04	0.10	0.50	6,880
‘Sweetheart’	Gi5	100	154.8	90.3	0.72	7.76	16	71,176
	Gi6	100	150.5	90.8	0.74	7.68	16.1	69,015
LSD ‘Sweetheart’ $P \leq 0.05$		-	10.7	6.7	0.07	0.17	0.23	8,189

Table 2. Performance of Gisela 5, Gisela 6, Gisela 12 and Mazzard cherry rootstocks with 'Lapins' and 'Regina' cherry cultivars over 8 years at Geneva, NY.

Cultivar	Rootstock	Tree survival (%)	Trunk cross-sectional area (cm^2)	Cum. yield (t/ha)	Cum. yield efficiency (kg/cm^2 TCA)	Average fruit size (g)	Average soluble solids (%)	Cum. crop value ($/ha)
'Lapins'	G5	100	123.6	52.4	0.55	8.7	15.3	49,311
	G6	100	137.4	50.5	0.51	8.9	15.4	48,598
	G12	100	192.1	53.5	0.37	9.4	15.3	61,806
	Mazzard	88	231.1	19.1	0.11	9.1	15.5	22,373
'Regina'	G5	100	107.3	35.2	0.42	11.6	17.7	57,592
	G6	100	154.8	28.9	0.25	11.6	17.5	48,410
	G12	97	182.3	29.9	0.22	12.2	17.5	53,203
	Mazzard	88	205.4	11.2	0.07	11.5	17.0	19,282
LSD $P \leq 0.05$		8	17.7	3.7	0.05	0.31	0.43	6,630

Figures

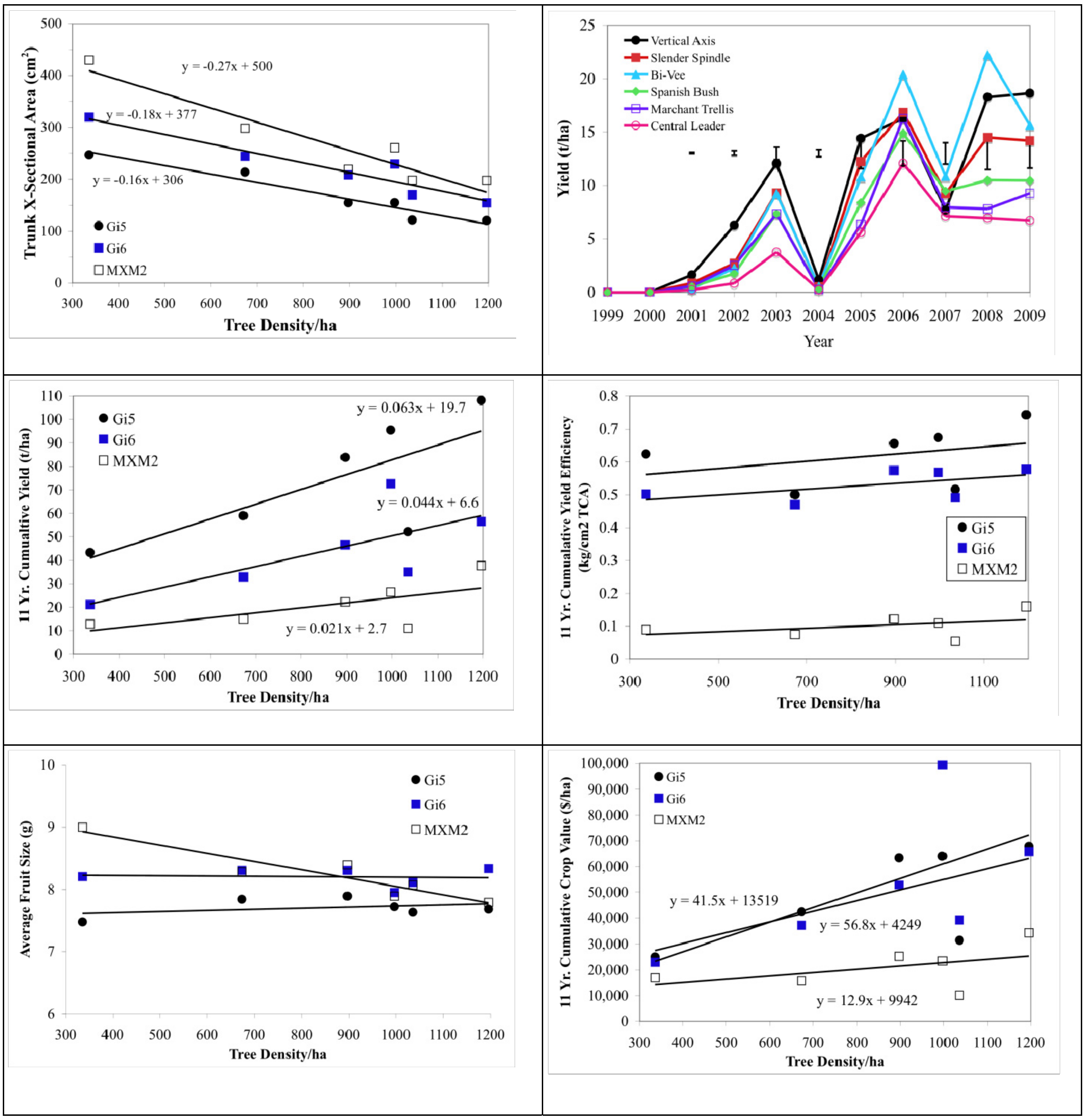

Fig. 1. Interaction of rootstock (Gi.5, 6 and MXM 2) and tree planting density on trunk cross-sectional area, annual yield, cumulative yield, yield efficiency, average fruit size and crop value of ‘Hedelfingen’ sweet cherry trees at Geneva NY over 11 years.

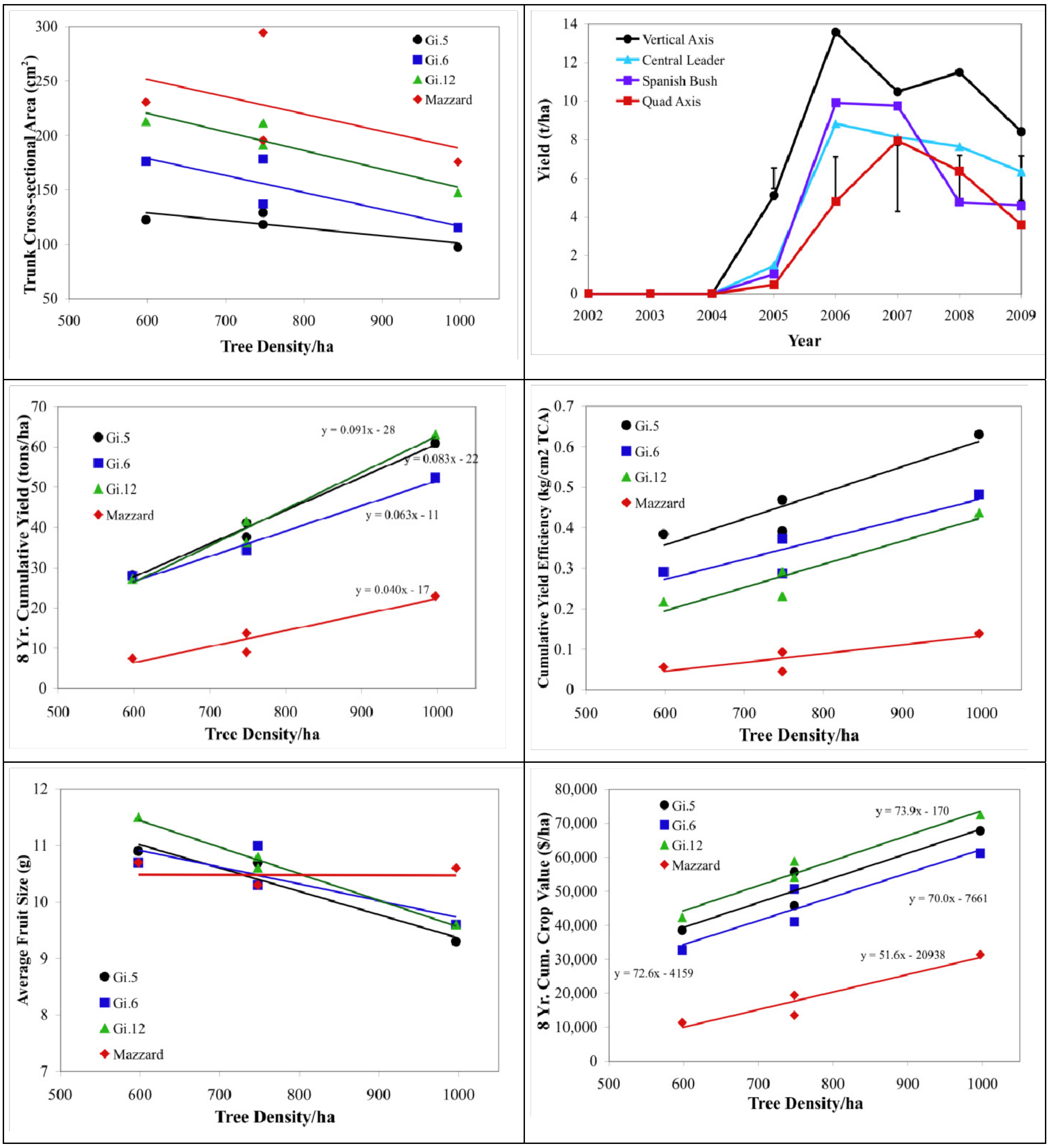

Fig. 2. Interaction of rootstock (Gi.5, 6, 12 and Mazzard) and tree planting density on trunk cross-sectional area, annual yield, cumulative yield, yield efficiency, average fruit size and crop value 'Lapins' and 'Regina' sweet cherry trees over 8 years at Geneva NY.