visable. The early spurriness and fruiting of the vertical shoot suppressed its vigor and size control became quite evident when compared to the central-leader trained trees (visual observation). Virtually no tying down of branches was needed on the vertical shoot in our angle trees in the subsequent years of production. Pruning was minimal in the angle system during the first 5 years of production in direct contrast to the spindle-trained trees. Not only was labor input lower in the angle-trained trees than in the other 3 training systems (little pruning or tying was required) but a high yield was also achieved.

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Yield and Fruit Quality of Apple Trees Under Three High Density Management Systems[1]

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Abstract

Comparisons were made in yield and fruit quality of apple (*Malus domestica* Borkh.) trees planted in 1979 and trained to the 3-wire trellis (1493 trees/ha), Lincoln canopy (1493 trees/ha) or Spindlebush (3986 trees/ha) systems. The cultivar and training system combinations included 'Golden Delicious,' 'Topred Delicious' and 'Starkrimson Delicious' trained to the 3-wire trellis, 'Golden Delicious' and 'Topred Delicious' trained to the Lincoln canopy, and 'Starkrimson Delicious' trained to the Spindlebush system. The cumulative yield of 'Golden Delicious' (from 1983 to 1986) was higher than 'Topred Delicious' and 'Starkrimson Delicious' on both the 3-wire trellis and Lincoln canopy. The cumulative yield of 'Topred Delicious' was comparable on the 3-wire trellis and the Lincoln canopy, but the annual production was more uniform in the latter. Individual tree yields of 'Starkrimson Delicious' were similar on the 3-wire trellis and Spindlebush, but the higher planting density of the latter resulted in significantly higher yield/ha. Fruit size and soluble solids in 'Topred Delicious' were higher on the 3-wire trellis than on the Lincoln canopy. The color and length/diameter ratio of 'Delicious' strains were not influenced by the training system.

Steadily increasing costs have created a need for increased production efficiency and higher production from each hectare of orchard. Grower response to these pressures has resulted in higher density plantings of fruit (4, 6, 9, 10). Apple trees in high density plantings are on dwarfing rootstocks which generally require support in the form of a trellis or a post. Various training systems for supported trees have been proposed and are being utilized in different parts of the world. Two commonly used systems of European origin include the vertical trellis and the Spindlebush (4, 6, 8). Recent trellising innovations in New Zealand have been directed not only towards the production of high quality fruit but also at mechanization of cultural operations (2, 3). The Lincoln canopy proposed for apples by Dunn and Stolp (3) radically alters tree shape and

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allows for mechanically harvesting dessert quality fruit. The adaptability of these systems to growing areas where the soil and climatic conditions may differ from the country of origin needs to be carefully evaluated prior to introduction. The problems and potentials of various commercial cultivars on these and other training systems are currently being evaluated at the West Virginia University Experiment Station. The present study reports on the performance of apple trees trained to the 3-wire trellis, Lincoln canopy, and Spindlebush systems.

Materials and Methods

Trees were planted in 1979 on Hagerstown silt loam soil in 91.4m long, N-S oriented rows at Kearneysville, VW. 'Golden Delicious,' 'Topred Delicious' and 'Starkrimson Delicious' on M.9 rootstock, spaced 1.83m x 3.66m (1493 trees/ha) were trained to a 3-wire trellis. The 1.83 m high trellis was constructed of pressure treated posts and high-tensile steel wire. The wires were 76, 127 and 178 cm above soil surface. Trees of 'Golden Delicious' and 'Topred Delicious' on M.26 planted 1.83m x 3.66m (1493 trees/ha) were trained to the Lincoln canopy (3) with a radial branch configuration. The height of the trellis was 1.22m and the horizontal cross arms were 1.52m wide with 8 support wires spaced 20cm apart. Trees of 'Starkrimson Delicious' on M.9 planted 0.91m x 2.74m (3986 trees/ha), supported by a 7.6 cm diameter pressure treated post extending 1.83m above ground, were trained to the Spindlebush system.

Training was accomplished primarily by pruning during the dormant season. For the 3-wire trellis 1 year old whips were initially headed at 61 cm. Three laterals on either side of the leader were tied to the trellis wires with vinyl tape. Laterals were trained at an increasing angle from the leader with increasing height in order to increase vigor in lower laterals and reduce vigor at the top of the tree. Trees of the Lincoln canopy were headed at 107 cm and laterals were tied in a radial configuration. Laterals were headed back when they reached the edge of the horizontal trellis. Vigorous upright growth was removed during the growing season. The Spindlebush trees were headed at 76 cm and attached to the treated post with a plastic tie. Wooden spreaders were used to train the 4 primary laterals. Clothes pins were used to spread weaker growth and shoots with high vigor were removed by summer pruning.

A ground cover of Kentucky-31 fescue was established between the rows immediately after tree planting. Recommended herbicide and pesticide programs were followed and all trees received uniform annual fertilizer application. Trickle irrigation was installed in 1983 and used when necessary. Following frost injury to blossoms in 1982 a wind machine was installed in the orchard block later in the year to provide frost protection in the future.

Yield data in 1983 and 1984 were obtained from a 91.4 row of each training system/cultivar combination. Data on yield, fruit quality and tree girth in 1985 and 1986 were recorded from 10 replicate trees in each system. At harvest fruit yield was recorded and trunk diameter measured 15cm above the graft union. The size of 10 fruit from each replicate tree was measured with a caliper and the surface color of 'Delicious' strains rated as Extra Fancy, Fancy or No. 1 corresponding to the U.S. grade standards for apples. Fruit firmness was determined with an Effegi penetrometer with an 11 mm plunger on 2 peeled sides of the fruit and soluble solids measured with hand-held Atago N-1 refractometer.

Results and Discussion

Comparisons of fruit yield. Data on fruit yield were not obtained during 1980 to 1982 because the systems were

yet being established during the first two years and due to frost damage in the spring of 1982. The annual and cumulative yields from 1983 to 1986 were influenced by both training system and cultivar (Fig. 1). 'Golden Delicious' produced higher initial and cumulative yields than the 'Delicious' strains on the 3-wire and Lincoln canopy trellis, both of which were at similar planting densities. Such differences in precocity between 'Golden Delicious' and 'Delicious' strains have been previously observed (11). Following a high yield in 1985, the 3-wire trellis trained 'Golden Delicious' showed a decline in production in 1986 (Fig. 1). A similar, although less dramatic reduction occurred with this cultivar on the Lincoln canopy. As in conventional plantings, annual thinning of trellised 'Golden Delicious' trees is necessary to avoid biennial bearing.

Although the cumulative yield of 'Topred Delicious' on the Lincoln canopy was similar to that on the 3-wire trellis (Fig. 1), the annual production was more uniform in the former. The 3-wire trellis trees produced more vigorous vegetative growth than those trained to the Lincoln canopy, which due to its horizontal limb orientation tends to initiate a higher number of spurs. This difference in canopy orientation is a probable cause for the higher initial yield on the Lincoln canopy.

Yield per hectare of 'Starkrimson Delicious' on both the 3-wire trellis and Spindlebush were low in 1983, but increased rapidly in subsequent years (Fig. 1). The difference in production between these systems is primarily a reflection of variations in planting density. This is illustrated by the similarity in individual tree yields between the two systems (Table 1).

Although these training systems result in entirely different canopy appearances, there were no significant difference in trunk area between the same cultivar on different training systems (Table 1). As would be expected, variations in vegetative growth were observed between different cultivars trained to the same system. A combination of a spur-type cultivar like 'Starkrimson Delicious' on M.9 results in a smaller tree than 'Topred Delicious' on M.9 and takes longer to occupy its allocated space. Although individual tree yields of 'Delicious' strains were not influenced by this variation in tree size (Table 1), higher

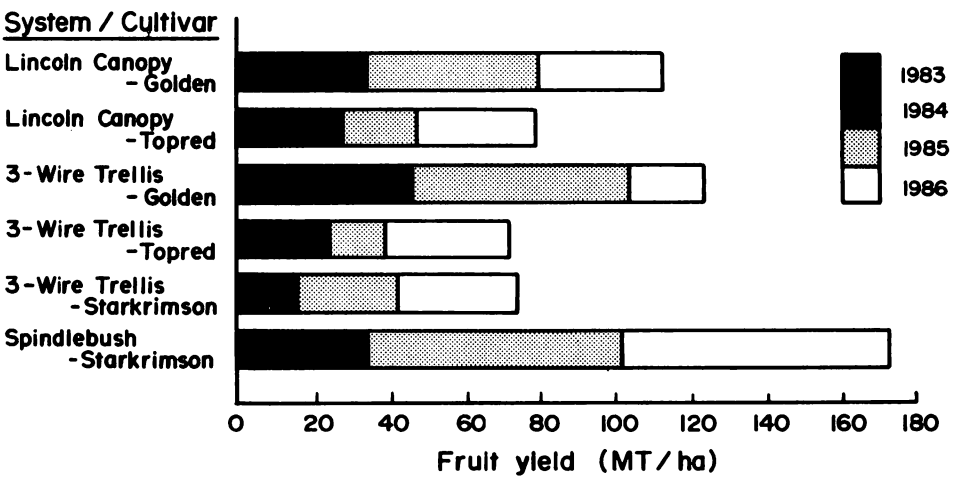

Figure 1. Annual and cumulative yields of 'Golden Delicious,' 'Topred Delicious' and 'Starkrimson Delicious' on different training systems.

Table 1. Influence of training systems on fruit yield and trunk cross sectional area of 'Golden Delicious,' 'Topred Delicious' and 'Starkrimson Delicious' apple trees.

System	1985			1986		
	Golden	Topred	Starkrimson	Golden	Topred	Starkrimson
			Yield (kg/tree):			
Lincoln Canopy	31.21a[z]	13.43b	---	21.59A	21.33	---
3-wire trellis	39.16a	10.43b	17.59b	12.54Bb	21.81a	21.71a
Spindlebush	---	---	17.09	---	---	17.70
			Trunk cross sectional area (cm^2):			
Lincoln Canopy	21.4	23.4	---	37.5a	28.1b	---
3-wire trellis	28.3a	27.1a	10.9b	38.8a	29.7a	17.3b
Spindlebush	---	---	13.5	---	---	15.9
			Yield (kg)/cm^2 trunk area:			
Lincoln Canopy	1.48a	0.63Ab	---	0.63	0.82	---
3-wire trellis	1.49a	0.40Bb	1.70Aa	0.40c	0.75b	1.28a
Spindlebush	---	---	1.27B	---	---	1.20

[z]Means by year and parameter with dissimilar letters are significantly different at P = 0.05 (upper case for columns, lower case for rows).

production per hectare may be obtained by using a slightly more vigorous rootstock with spur-type strains (1). The large increase in trunk size and reduction in yield/cm^2 trunk area in 'Golden Delicious' trees between 1985 and 1986 (Table 1) indicate that these trees underwent increased vegetative growth in 1986 and reinforce the earlier observation that they are tending towards biennial production.

Comparisons of fruit quality. Fruit size of 'Topred Delicious' on the 3-wire trellis was larger than that on the Lincoln canopy in both 1985 and 1986 (Table 2). A similar situation was observed in 'Golden Delicious' in 1985. The lack of difference in tree yield between these systems implies that the Lincoln canopy is setting a higher number of fruit which are smaller in size. This could be a result of a higher spur production due to horizontal orientation of limbs. However, it is more likely due to reduction in light penetration into the canopy due to the vertical growth of the current seasons growth above the fruiting surface. Rom and Ferree (7) have demonstrated that shading of shoots late in the season reduced fruit size in apple trees grown under controlled environment conditions.

The system of training did not influence fruit firmness of 'Golden Delicious' or 'Topred Delicious' (Table 2). However, 'Starkrimson Delicious' on the 3-wire trellis produced consistently firmer fruit than Spindlebush trees. The reason for this variation is not clear.

Soluble solids were consistently higher in 'Topred Delicious' on the 3-wire trellis than the Lincoln canopy in both years and also in 'Golden Delicious' in 1986 (Table 2). The higher soluble solids in 'Golden Delicious' on the 3-wire trellis in 1986 may be a reflection of the lower yields on this trellis as compared to the Lincoln canopy (Table 2). However, the lack of difference in fruit yield in 'Topred Delicious' between these systems indicates that the lower soluble solids in fruit on the Lincoln canopy is not caused by differential crop loads. A reduction in soluble solids due to shading of shoots during the later portion of growing season has been reported earlier (7). Thus the concomitant reduction in fruit size and soluble solids indicates that both these

Table 2. Influence of training systems on fruit quality of 'Golden Delicious,' 'Topred Delicious' and 'Starkrimson Delicious' apple trees.

System	1985			1986		
	Golden	Topred	Starkrimson	Golden	Topred	Starkrimson
			Fruit diameter (cm):			
Lincoln Canopy	7.36Bb[z]	8.24Ba	---	7.64	7.48B	---
3-wire trellis	7.60Ac	8.74Aa	7.82b	7.71b	7.93Aa	7.68b
Spindlebush	---	---	7.68	---	---	7.52
			Fruit firmness (N):			
Lincoln Canopy	68.4a	56.8b	---	66.5	64.8	---
3-wire trellis	67.9a	54.0	68.8Aa	68.4a	65.6b	68.9Aa
Spindlebush	---	---	64.4B	---	---	57.7B
			Soluble solids (%):			
Lincoln Canopy	13.5b	14.1Ba	---	13.2Ba	11.6Bb	---
3-wire trellis	13.5b	15.5Aa	12.8c	14.9Aa	13.8Ab	12.6c
Spindlebush	---	---	12.4	---	---	12.6

[z]Means by year and parameter with dissimilar letters are significantly different at P = 0.05 (upper case for columns, lower case for rows).

parameters may be improved by increasing light penetration into the canopy.

The training systems had no significant influence on the fruit length/diameter ratio of 'Delicious' strains. The differences in the red coloration of fruits of these strains were not significant, even though fruit from the Lincoln canopy appeared to have a lower coloration. The lack of a significant difference may have been caused by the wide latitude in the rating scale used.

These results indicate good to excellent production of these cultivars on the 3 training systems. The response of different cultivars trained to the same system can be quite variable. This was especially evident with 'Starkrimson Delicious' showing reduced vegetative vigor, whereas 'Topred Delicious' produced a large tree prone to excessive vegetative growth. Fruit production on the Lincoln canopy was comparable to that on the 3-wire trellis and the annual production was more uniform. Thus this system which was specifically designed for mechanical harvesting of dessert quality fruit (3) shows commercial potential equal to systems designed for hand harvest. However, research is needed on cultural practices to improve fruit quality, especially under the environmental conditions in the eastern U.S. We are currently examining the influence of different summer pruning treatments on light penetration and fruit quality in the Lincoln canopy.

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Variety Fact Sheet—GALA

JAMES K. BALLARD

Cultivar Name: Gala. Synonyms: none known. Strains and Patent Status: (Std) Gala (TM), (Kidds D-8) Plant Patent 3637; Royal Gala (TM) (Tenroy) Plant Patent 4121; Imperial Gala (TM) (Mitchell); Regal Queen Gala (Kiddle); Regal Prince Gala (Fulford); Scarlet Gala (Creech) Plant Patent Pending; Spur Gala-go-red (Cooper) Patent applied for. Origin of Gala: A bred variety from New Zealand, 1960. Parentage: Kidds Orange Pippin x Golden Delicious.

Fruit Description

Size range: small to medium. Stem length: long. Skin russet: generally free. Flavor: very sweet & aromatic. Texture: fine, firm and crisp. Maturity date: about a week to ten days ahead of Jonathan. Flesh color: yellow to cream. Fruit shape: uniform oval round. Skin color: pale to golden yellow with bright red stripes or blush red depending on the strain or amount of reversion. Storage life: about 3 months.

Tree Characteristics

Vigor: vigorous and upright, similar to Golden Delicious. Produces good strong wide angle crotches. Growth type: semi-spur. Precosity: a very precocious annual bearer. Bloom: midseason. Pollination requirements: any diploid in same bloom season except Golden Delicious or Kidd's Orange (intersterile). Cold hardiness status: hardy. Disease status: susceptible to mildew, scab and fireblight. Virus indicator for Rubbery Wood. Physiological disorders: fruit is stressed with high summer heat prior to harvest. Over-maturity will produce stem end cracking.

Availability sources: Gala and Royal Gala are offered by Stark Bros., Carlton Plants and Van Well Nursery. Imperial Gala is offered by Hilltop Trees. Scarlet Gala is offered by C & O Nursery. Spur Gala-go-red is offered by Knowlview Nursery.

Commercial status: commercial trials of growing and marketing indicate limited promise for some growers.

Grower Testing Comments

(Eastern Washington): Probably the best variety to brighten the lull between the old and new crops of Red Delicious. The color factor of all the red strains appear to show frequent reversions. All the Galas require several pickings in order to maintain uniform maturity.

The hardiness factor appears to be equal to Golden Delicious as demonstrated with bark splitting on young trees in 1986.

The high vigor of Gala is capable of producing fruit buds on one year shoots. Gala responds very well to two sprays of Elgetol 2/3 pint 3 days apart plus Sevin later.

"It's the first *good* sweet apple of the summer with excellent identifiable eye appeal. We cannot detect any difference in taste between Gala and Royal Gala at Wapato."