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A NEW GRAPE SHAPING METHOD IN THE SOIL-BURY OVER-WINTERING ZONE OF ARID AND SEMIARID AREAS

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Abstract

There are many shaping methods in the soil-burying over-wintering zone of arid and semiarid areas. However, these pruning techniques are very complicated for mechanized operations and it's difficult for soil-burying and water saving irrigation. This article proposed a new shaping method which suits for soil-burying zone of arid and semiarid areas. The main features of the 3 shaping methods [Multiple main vine fan-training (MVF), Cordon-training (CT) and Crawled Cordon Training (CCT)] were comparatively analyzed, and 3 methods'-main labour items and their elapsed time in winter pruning were figured out. The stable yielding ability, grape quality and disease occurrence for these three methods were studied from year 2005 to year 2009. CCT shaping method avoided the unmounting in winter and mounting in spring, as a result it was found easy for mechanized operations. Compared to MVF and CT, single worker's labour time per 667.7 m^2 from winter pruning to spring unearthing in CCT was decreased 37.50% and 27.08%, respectively. The contents of soluble solid, reducing sugar and titratable acid in grape of the three different shaping methods had no significant difference. The stable yielding ability in CCT was significantly higher than the other two methods. The clusters' infection rate of grape anthracnose, white rot and botrytis cinerea were high but the berries' infection rate was much lower. CCT shaping method promote a model of durable viticulture, with the objectives of high quality, stable yield, long-lived and artistic vine production in soil-burying over-wintering zone of arid and semiarid areas.

Introduction

Grape skin and seed are good sources of important bioactive components such as phenolics, anthocyanins and antioxidants (Ghafoor *et al*., 2011). China has made great progress in viticulture and wine industry, but the excellent viticultural regions distributed mostly in soil-burying over-wintering zone of arid and semiarid areas. Chinese viticulture area with 4.513 million ha area and average yield of 71.51 million tons ranked fifth and third in the world (Luo, 2010). However, the traditional shaping methods such as Multiple Main Vine Fan-training (MVF) and Cordon-training (CT) are not adapted to mechanized production at present and the grape shaping method becomes the significant problem in restricting the sustainable development of viticulture and wine industry in China (Li *et al.*, 2009).

Viticulture management focuses on improving the grape's maximum potential production and achieving mechanization. However, the standardization of viticulture is the prerequisite of the mechanization in the integrate vineyard managements. The successful design of vine shape is the key factor whether mechanized operations during grape harvest and soil-burying could be carried through, and it also determines the quality and efficiency of these operations (Hu, 2005).

Along with the enlargement of the viticulture areas, the contradiction of labour demand between vine and other crops becomes more obvious. Mechanization of vine production is in urgent need for improving labour efficiency, decreasing labour intensity and cutting down the production cost (Zhao, 2008). Therefore, the shaping methods develop towards simplification and mechanization of reducing labour will be the only way to realize industrialization and socialization of the vine production (He, 1999).

In order to improve work efficiency and lower labour intensity of soil-burying process, some researchers (Luo *et al.*, 2010; Liu *et al.*, 2009) studied the cold-proof effect of covering and soil-burying. They found that although the covering materials reduced the labour intensity, those materials had short durable years and poor effect on varieties with poor cold resistance. Shaping methods in China are mostly MVF and CT, which could put off thickening of the main vine so that it is convenient for the soli-burying; However, the irregular fruiting may cause poor quality grapes, and the grape was soil-buried in winter and unearthed in the follow spring will increase labour intensity and cost (Li, 2001). For slant-trunk of horizontal shaping model to over winter, its main trunk can be pressed down easily, thus the trunk could avoid fracturing. This shaping model is convenient for soil-burying, and meantime decreasing the amount of soil and the cost of soil-burying and unearthing, but it does have drawbacks which are shorter quantity of vines per area and less economic benefits (Li *et al.*, 2006).

The experiments adopted a new shaping method called Crawled Cordon Training (CCT) (Li *et al*, 2010) (Fig. 1) in soil-burying over-wintering zone and the other two traditional shaping methods (MVF and CT), the main characteristics and their effects were compared and analyzed, such as time consuming of main work items, stable yield ability, effect of disease control, and berry quality, which provide CCT for sustainable development of vine production in soil-burying over-wintering zone and establishing theoretical basis for its popularization and application.

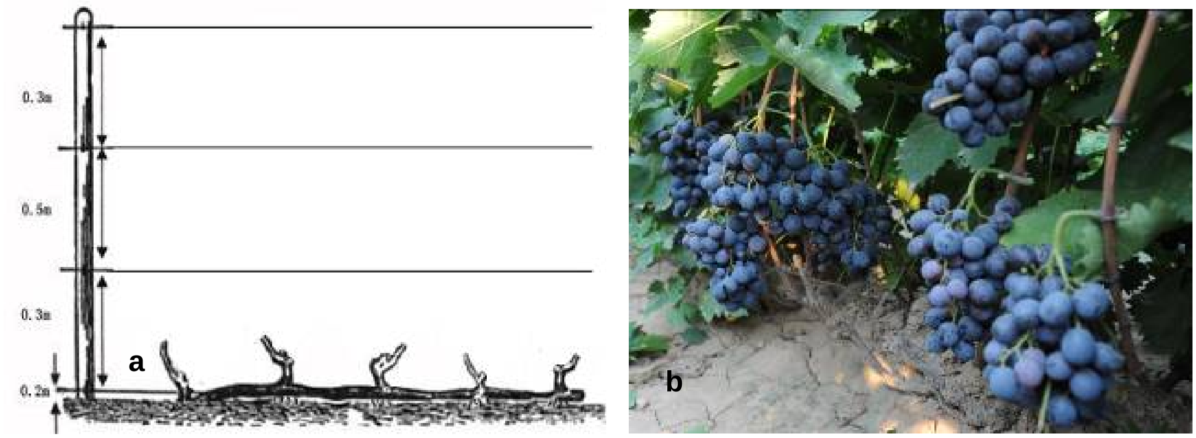

Fig. 1. CCT shaping method. The sketch map of CCT shaping method after winter pruning (a) and the photo of CCT shaping method before harvest (b).

Materials and Methods

Vineyard: The vineyard selected for the study was located in east longitude 111°02'~111°41', latitude 34°02'~35°19', with the altitude of 450 m ~560 m. The average annual accumulated temperature was 4490.5°C with 2242.83 h sunshine time, 205.4 d frost-free period and 597.5 mm concentrated rainy season.

Soil (yellow loam) samples were obtained by intersection line 5 points method in December, 2009. The samples which come from different sites but same level were blended, air dried and then sieved. Soil nutrient indices were measured by assay method of Lu (1999), 0~60 cm layer 14.0 g/Kg soil nitrogen, 17.68 mg/Kg available P, 71.89 mg/Kg alkali hydrolysable, 209.60 mg/Kg available K, 14.08 g/Kg organic matter, and 8.43 pH.

Materials: Twelve-year-old Cabernet Sauvignon (*V. vinifera* L.) planted at 1.0×2.3 m (vine × row) spacing, using MVF, CT and CCT shaping methods, with fifteen rows for each experimental plot, 5 rows for each shaping method, 150 vines for each row, under randomized block arrangement were selected for the experiment. The middle three rows of each experimental plot were selected for testing and analyzing. The experiments were conducted over five consecutive seasons of 2005 to 2009.

Shaping methods: For MVF model, three main vines were kept and bud picking apart from 40cm in the ground. Every main vine keeps one fruit-bearing shoot per 10cm, and every plant keeps twelve fruit-bearing shoots. Single shoot renewal method was used for winter pruning. The support surface was 1.9m and the main vine's height was kept under the third iron wire. CT adopted slant model of single dragon cordon was shaped with 1.9m support surface, and the angle between dragon cordon and the earth surface was 60°. No shoot was kept under the first iron wire (40cm apart from ground). The fruit-bearing shoots distributed equably in dragon cordon of the first iron wire with one fruit-bearing shoot group per 20cm and 3 fruit-bearing shoots per group, thus there were four fruit-bearing shoot groups and 12 fruit-bearing shoots per vine altogether. CCT adopted perennial double CCT planting method with 1.9m support surface. Each horizontal CCT shoot distributed six fruit-bearing shoots with twelve fruit clusters per plant.

Thirty vines chosen randomly for every shaping method between 2005 and 2009, and numbers of incisions were evaluated and accounted by its average value. The labour time for pruning, unmounting and soil-burying in winter, unearthing and mounting in next spring were counted up and then calculated the time consuming of main labour items per capita of fifteen skillful workers in the vine yard.

Scanning electron microscope: In January, 2010, the node incision of the main vine and the slices which from 1 cm up and down the node incision were sampled for scanning electron microscope (Perveen & Qaiser, 2012; Dogu *et al*., 2012). The control sample was chosen from the node of main vine which had no incision. Each sample was free-hand sectioned in transverse direction at 2, 4, 6, 8, and 10 mm below the pruning cut. Stem discs between these sections were taken at the same time, and some were prepared for Scanning Electronic Microscopy observations of tylosis development in individual vessels following the protocol mentioned.

The sections were temporarily mounted with a cover slip in water for light microscopy. Five areas, each containing 40-50 vessels and including some consecutive xylem sectors bounded by rays, were chosen randomly for analysis.

All vessels in each area were categorized as vessels without tyloses, vessels partially filled with tyloses, or vessel completely occluded with tyloses. Two parameters, percentage of vessels with tyloses (PVT) and percentage of vessels occluded completely by tyloses (PVO), were calculated to quantify tylosis development.

Yield components: Yield components were assessed at harvest. The number of clusters and total vine yield per vine were determined by 10 vines per plot. Crop weight and number of clusters per vine were used to calculate cluster weight. Yield per ha was then calculated according to vine density. The total vine yield per vine was

determined by 30 vines per plot. Yield per 667.7 m^2 was then calculated according to vine density at the site.
According to improved ABC (Alternate Bearing Coefficient) assay method of Jing & Wu's (1986), the stable yielding ability was determined for each shaping method. In order to avoid norm deviating which caused by alternate bearing, the average yield of the first year yield (X_{i-1}) and the third year yield (X_{i+1}) was taken as the second year yield (X_i) in three continuous years.

$$\text{A}\ \sum\left|\frac{\frac{X_{i-1}+X_{i+1}}{2}-X_i}{\frac{X_{i-1}+X_{i+1}}{2}}\right| \Big/ \text{(therecord years-2)}$$

Namely,

$$\text{A} = \sum\left|1-\frac{2X_i}{X_{i-1}+X_{i+1}}\right| \Big/ \text{(the record years-2)}$$

Note: The smaller Index A, the greater yield stability.

All clusters were frozen and stored at -18°C for fruit composition analysis and defrosted overnight before composition analysis. A berry subsample (300 berries) was hand crushed and filtered. Total soluble solid concentration was determined by using a temperature compensating digital refractometer (Atago, Tokyo, Japan). A 50mL ample was used to determine titratable acidity and reducing sugar according to the method of Anon., (1990). An automatic titrator, coupled to an autosampler and control unit (Titroline 96, Schott, Germany) was used to determine titratable acidity (expressed as tartaric acid). The remaining berry subsample was homogenized using a knife mill (Retsch, Grindomix, Germany) at high speed (10,000 rpm for 30 sec).

Disease investigation: Fruit disease investigation was conducted from 2005 to 2009 in harvest period by measuring five vines randomly per shaping method of each plot, and the numbers of the diseased and total fruit were recorded, meantime the diseased panicle rate and diseased fruit rate were calculated (Marchetti *et al*., 1984; Kummuang *et al*., 1996).

Statistical analysis: Statistical analysis was conducted by JMP 9.0 for Windows with three replications of the same sample. All data were subjected to analysis of variance, and the means were compared by Tukey's test at 5% probability.

Results and discussion

Effect on labour projects, time and incisions: Data indicated that the vines which shaped by CCT method didn't need unmounting before soil-burying and without mounting after spring unearthing, thus favouring mechanization of winter pruning (Table 1). Compared to MVF and CT, using CCT shaping method, the labour time per 666.7 m^2 of one worker working from winter pruning to spring mounting was reduced for 37.50% and 27.08%, respectively. This could be because the former two shaping methods had trivial details in winter pruning, thus using too many operations (eg. pinching and sublataral shoots removaling) and leaving more incisions as a result. In most of the vineyards, MVF and CT needed pruning sublateral shoots and pinching bearing branches repeatedly in summer, so it surely raised the input of labour. However, by CCT method, with 0.5 m×1.5 m (width × height) support surface, the shoots which grown out of this surface were all cleaned. Thereby, CCT method avoided the operations like pruning sublateral shoots and pinching bearing branches etc., as a result, it solved the problems of long labour time and high labour intensity that existed in traditional vine shaping methods.

Table 1. The main vineyard labour items and time-consuming investigation of different shaping methods in full fruit period (2005-2009) (h/666.7m^2).

Treatment	Shearing fracture	Time consuming of winter pruning (h)	Unmounting	Soil-burying (h)	Unearthed (h)	Mounting
MVF	25~30	32	+	34	24	+
CT	10~16	27	+	44	21	+
CCT	8~10	12	-	24	23	-

Note: "+" stands for "Operating", "-" stands for "No operation

Besides variety characteristics and environment factors, viticulture technology influenced the yield and quality of the vine and wine directly. Vine is a liana plant which has marrow, the elongation of the perennial parts will cause vine cavity and increase the transportation distance of nutrients. As we all known, pruning is the indispensable segment of the vine production (Galel, 2000). But after pruning, the vessel once blocked by tyloses (Schmitt & Liese, 1993; Sun, 2006) showed higher intensity of vessels blocking in the preceding years along with the growing tree-age (Cochard & Tyree, 1990). Consequently, the sap flow and transportation of the nutrients are blocked. Eventually, grape yield and quality decreased.

Pruning, a viticulture practice to maintain grapevines' vigour and health (Morton, 2000), may lead to physical damages and tyloses formation in the xylem vessels. The presence of vessel elements, whether partly or completely blocked, can profoundly affect the patterns of water movement within the developing xylem networks (Sellami & Sifaoui, 2003). The experiments showed that 93.1% of vessels had tyloses in shoot with incision, and among which 47.3% were totally blocked (Fig. 2-b), while vessels in shoot without incision had fewer tyloses (Fig. 2-a). Data showed that when adopting CCT shaping method, minimum incisions in winter pruning were produced, and the grape would be much more vigour and healthy.

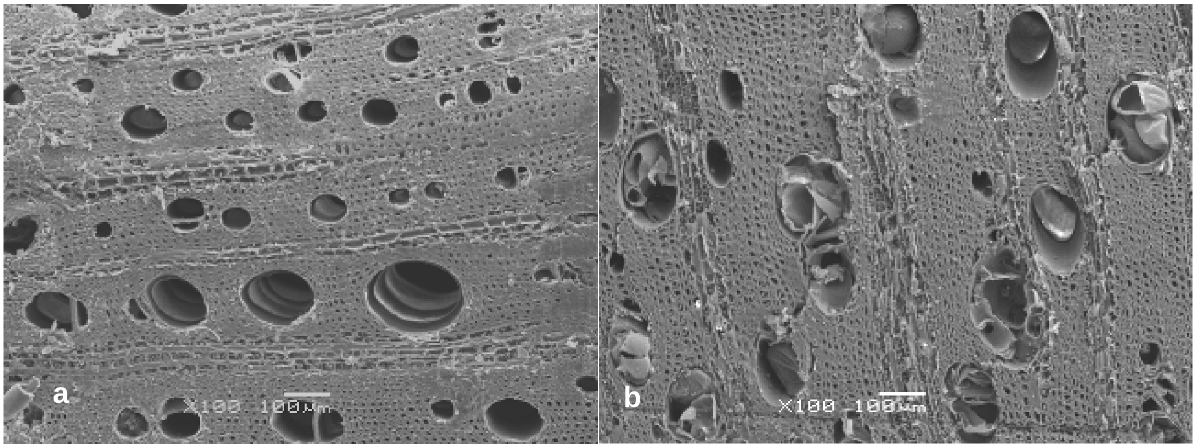

Fig. 2. The scanning electron microscope photos of the vine xylem. Without incision, the vine's xylem vessel had few tyloses (a) and with incision, the vine's xylem vessel had plenty of tyloses (b).

Yield stability: According to Table 2, CCT and CT showed significantly lower A values which represent higher yield stability compared with MVF. There was no significant difference between CT and CCT. The yield stability order was: CCT>CT>MVF.

It's known that fruit trees may appear biennial bearing with poor yield stability, this not only caused the drop of the yield, quality and commercial value, but also weakened the tree vigor, thereby it can aggravate the occurrence of the disease and pest injury, shorten the fertility age and cause severe economic loss. CCT shaping method favored for yield control and without nutrients deficiency and vine ageing, therefore it achieved the high quality and stable yield of the vine production. Yield (2009) in Table 2 had general drop, the reason was that the vines have been suffered cold damage because of low temperature (about -17°C ~ -15°C) in winter of 2008. In CCT method, the trunk had a large number of root systems and supported abundant nutrients to shoots, thus the shoots had high cold resistance, and as a result, the yield decline varied in a small range; the trunk of CCT vines was below earth surface 20cm which had little influence suffered by the air temperature. Under the drought conditions, lifting water effect could assure that roots absorbed water from relatively deep and moist soil layer at night (Li *et al.*, 2003), thereby guaranteed roots from the dry layer surface not to die and kept absorbing nutrients from the nutritious soil (Caldwell & Richards, 1989). At the same time, lifting water effect enhanced the utilization effect of nitrogen, phosphorus and potassic fertilizer in shallow layer (Fan *et al*., 1996). After the chemical transforms, nitrogen went along to berries and shoots, but low water application efficiency would influence this procedure. Internodes of the perennial CCT cordons which is close to the earth generated lots roots, therefore the vine had high efficiency of water application and nitrogen level, the yield and quality of vines had been improved, the maturation of the shoots was also promoted (Weyand & Schultz, 2006a; 2006b; Xi, 2007).

Table 2. Yield (kg/666.7m^2) and (A value) of different shaping methods in recent five-year (2005-2009).

Treatment	2005	2006	2007	2008	2009	A value
MVF	810.42	869.88	750.72	812.26	429.63	0.2180 A
CT	782.72	930.22	993.94	780.87	420.02	0.1070 B
CCT	692.08	721.78	781.88	746.46	595.16	0.0837 B

Different ordinary form letters or capital form letters in same line show LSD test reached the level of significant difference ($p<0.05$) or great significant difference ($p<0.01$), same letters show the level of no significant difference.
Note: The smaller Index A, the greater yield stability.

Grape quality: The reducing sugar was not significantly affected by shaping method (Fig. 3-a). Titratable acid in CT was lowest, it had significant difference between MVF and CT, while only in 2006 there's significant difference between MVF and CCT. However, the significant difference of titratable acid between CT and CCT was different in different year (Fig. 3-b). Soluble solids of CT was higher than MVF and CCT every year except in 2006, and it was not significant except in 2005, and there was also not significant between MVF and CCT (Fig. 3-c).

For MVF method, vines had different fruit setting sites, different ripening degree, and poor ventilation effect, forming high humidity of the surrounding microclimate, thus declined grapes' transpiration rate and liquid flow to the berries. What's more, it also decreased the assimilates accumulation directly or indirectly, MVF may present high humidity because the canopy closure and this would cause fungus disease easily as well as yield and quality decline of the grapes (Zhang *et al*., 2009). Berries were easily been shaded in MVF, and shaded berries may have a lower soluble solid content and a higher titrable acid compared to the berries which were unshaded (Macaulay & Morris, 1993; Dokoozlian & Kliewer, 1996; Mabrouk & Sinoquet, 1998).

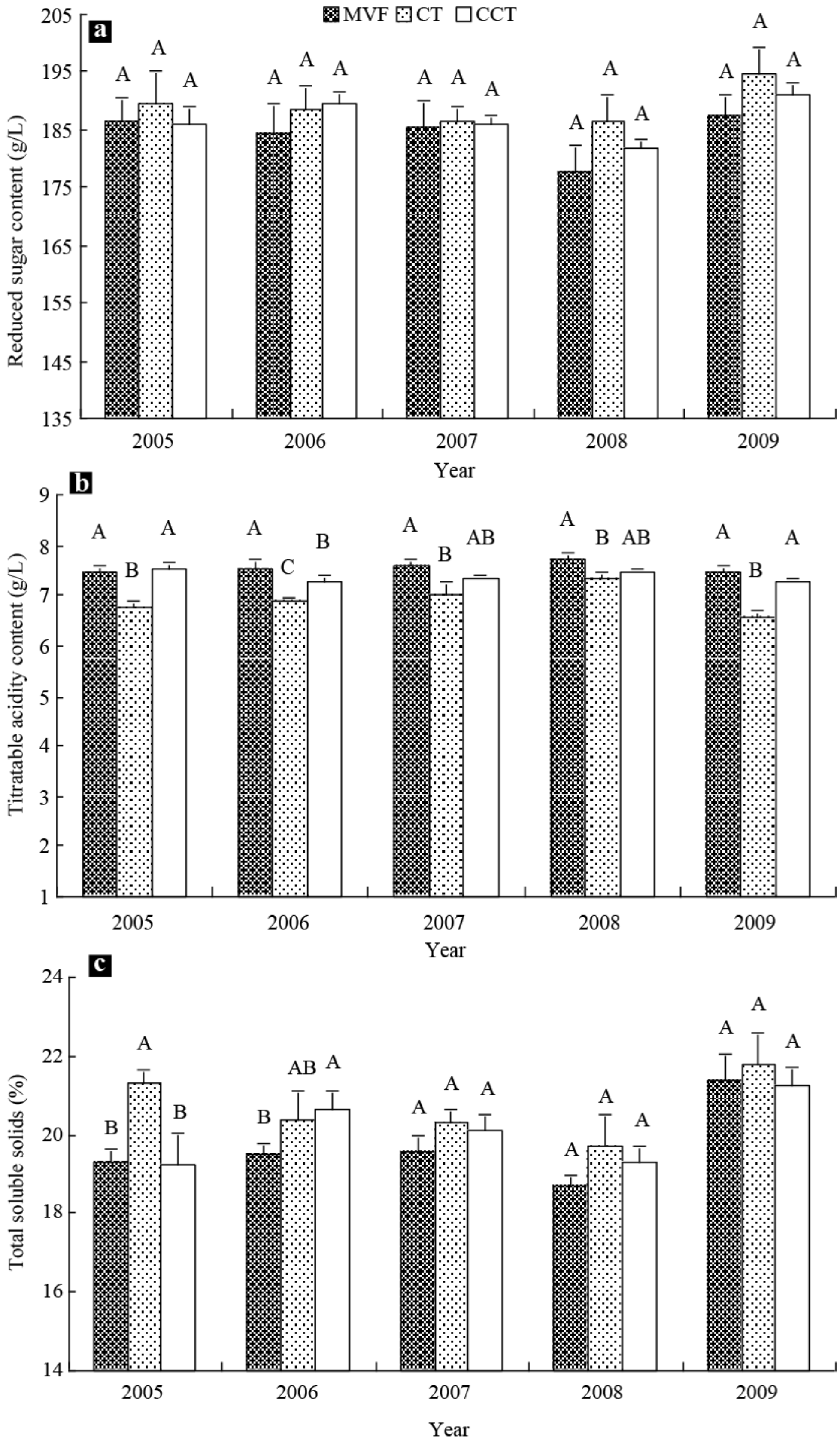

Fig. 3. Quanlity of different shaping methods in recent five-year. Reduced sugar content (g/L) (a), titratable acidity content (g/L) (b) and total soluble solids (%) (c).

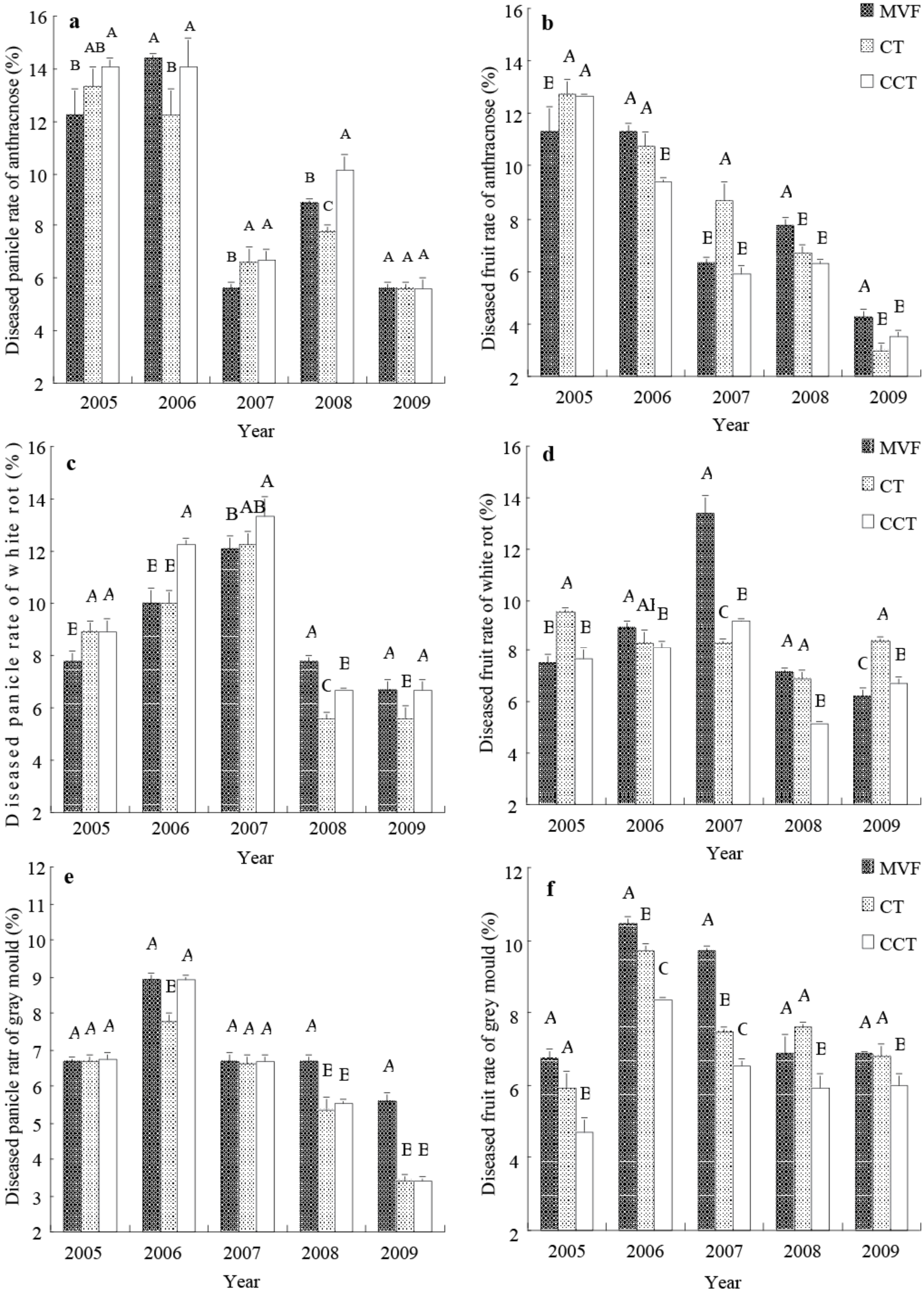

Fig. 4. Comparison of disease indices of major diseases of different shaping methods. (a, c, e): Diseased panicle rate of anthracnose (a), white rot (c) and grey mould (e). (b, d, f): Diseased fruit rate of anthracnose (b), white rot (d), grey mould (f).

The fruit setting height of CCT was 20cm to 30cm, thus promoted the transportation and utility of the nutrients to clusters; in development of the vines, the aged leaves and the leaves which close to the earth were cleaned in time, so vines had fine illumination conditions, strong respiratory intensity and certain photosynthetic capacity, meanwhile, the content of macromolecule acids broke up into micromolecule acids increased (Zhao, 2003). In addition, CCT benefits for the accumulation of sugars, it may explain that the controlled vines had lower fruit setting site and accepted more latent heat from the earth surface which impelled the berries had a high temperature. And in CCT method, with the high temperature, it increased the berries' sugar content and therefore the berries had a high ripening degree (Buttrose *et al*., 1971). Grapes from CT shaping method had the highest sugar content and soluble solid content, but it's with the lowest content of titrable acid.

Berry disease: From the field investigation of fruit diseases, there were three main and severe diseases in Cabernet Sauvignon in Xia county, Shanxi province: grape anthracnose [*Glomerella cingulata* (*Ston.*) Spauld et Schrenk], grape white rot [*Coniothyrium diplodiella (Speg.)* Sacc] and grape grey mould (*Botrytis cinerea Pers.*).

Data showed that the diseased fruit rate of anthracnose of CCT was significantly lower than that of MVF and CT (Fig. 4-a), and the diseased fruit rate of anthracnose in CCT shaping method was higher than MVF shaping method except in 2005, and in other years it was lower than MVF. Moreover, the two rates have significant difference in 2006, 2008 and 2009. Compared to CT, the diseased fruit rate of anthracnose of CCT was higher just in 2009, but in other years it was lower than MVF and CT. The diseased panicle rate of anthracnose of CCT was lower than MVF, while in other years it was higher than MVF and CT shaping methods and with different significant difference in every year (Fig. 4-b).

CCT exhibited higher diseased fruit rate of grape white rot than other 2 shaping methods, only in 2008 it was lower than MVF. The diseased fruit rate of grape white rot in CCT and MVF shaping methods have significant differences in every year except 2009. For the diseased fruit rate of grape white rot (Fig. 4-c), it's interesting to find that there's difference in significant rules with CT and CCT and there's no significant differences in MVP and CT. Furthermore, it has diverse diseased panicle rate of grape white rot in these three shaping methods (Fig. 4-d).

For the vines of different shaping methods, the diseased fruit rate of grape grey mould was higher than MVF and CT in 2005 and 2007, but only in 2006 it has significant difference between CT and CCT; the diseased fruit rate of grape grey mould of CT and CCT was lower than MVF in 2008 and 2009, and there's no significant difference in CT and CCT (Fig. 4-e). The diseased panicle rate of grape grey mould in CCT shaping method was lower than MVF and CT, and the same rate in MVF was much higher than CT shaping method (Fig. 4-f).

The researches showed that when increasing the fruit bearing site to above 40 cm in grape's growth and development, it can reduce the infection of funguses (Zhang *et al.,* 2010). The main berry diseases were funguses, they may bear spores easily in humid environment and make the number of diseased fruits increased. The fruit bearing site of CCT shaping method was relative higher than other traditional shaping methods, but it has a segregated fruit bearing zone and photosynthesis zone, so that it is convenient to control grape diseases. In CCT shaping method, the anthracnose, the grape white rot and the grape grey mould were not significant higher than MVF and CT.

Conclusion

CCT shaping method can reduce the labour intensity in vineyard management as well as save working hours and cost. The vines have fewer incisions and less tyloses produced, beneficial for vines' vigour, health and stables yield. CCT also has a low fruit bearing sites, thus the ripeness of grapes was nearly the same and matured 5-8 days earlier than MVF and CT. With the help of reasonable management measures, it can reduce the damage of diverse diseases effectively which occurred in CCT vines, realize the objective of viticulture with high quality, stable yield, longevity and beauty.

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