SCIENTIFIC WORKS OF THE LITHUANIAN INSTITUTE OF HORTICULTURE AND LITHUANIAN UNIVERSITY OF AGRICULTURE. SODININKYSTĖ IR DARŽININKYSTĖ. 2006. 25(3). 364–370.

CHLOROPHYLL FLUORESCENCE CHARACTERISTICS OF CULTIVAR 'AUKSIS' ON ROOTSTOCKS P 22 AND P 60 IN HIGH DENSITY ORCHARDS OF DIFFERENT CONSTRUCTION

Gintarė ŠABAJEVIENĖ[1], Jurga SAKALAUSKAITĖ[1], Vytautas ŠLAPAKAUSKAS[2], Nobertas USELIS[1], Pavelas DUCHOVSKIS[1]

[1]Lithuanian Institute of Horticulture, LT–54333 Babtai, Kauno 30, Kaunas distr., Lithuania. E-mail: G.Sabajeviene@lsdi.lt

[2]Lithuanian University of Agriculture, LT–53067 Akademija, Studentų 11, Kaunas distr., Lithuania

Fluorescence parameters in apple tree leaves of cv. 'Auksis' on rootstocks P 60 and P 22 were investigated at the Lithuanian Institute of Horticulture in 2005. Apple trees were trained as spindle, slender spindle, slender spindle V form, free leader axis, super spindle and super spindle V form. Orchards on rootstock P 60 were planted using 3 x 1.5 m; 3 x 1.25 m; 3 x 1 m and 3 x 0.75 m planting scheme, apple trees on P 22 – 3 x 1 m; 3 x 0.75 m; 3 x 0.5 m and 3 x 0.25 m. planting scheme. A fall in fluorescence parameters due to the higher planting density proves that the researched fruit trees experienced stress. However, with every further enlargement of planting density, the mentioned parameters were changing positively. That enables to conclude that the examined apple trees experienced competitive stress. Distinct fluorescence parameters of different rootstocks show that the response of the fruit tree within inter-competition depends on the rootstock type. The open tree forms allow optimum light interception. This feature determinates high photochemical efficiency in leaves. The highest quantum yield and electron transport were detected in super spindle V form and slender spindle V form apple trees.

Key words: apple tree, density, electron transport rate, maximum fluorescence, minimum fluorescence, quantum yield, rootstock, tree form.

Introduction. Since the late 1980's there has been a rapid increase in planting density of apple trees in different regions of Europe (Mantinger and Vigl, 1999). About ten years later, Widmer and Lemmenmeier (1999) showed that the highest yield was in orchards with 10 000 trees per ha. The planting system and tree form is crucial for growth, productivity, yield and fruit quality in apple orchard (Uselis, 2003).

Different kinds of fruit trees request specific physiological conditions for their growth and development. Aberration from optimal conditions can lead to a stress. Investigations of other scientist groups demonstrated that fruit tree density influences crop yield and fruit quality (Stampar et al., 1998). With increase of planting density, productivity per tree decreases, whereas cumulative productivity per hectare increases (Jackson et al., 1981; Mika and Piątkowski, 1986). Training and formation of fruit tree directly and indirectly affects the size of assimilation area, as well as the intensity of photosynthesis. The importance of rootstocks is more and more widely recognised, which, in terms of their influence on crop productivity, are not less important than the grafted scions.

Fluorescence is proved to be especially effective for quantifying the effects of environmental stress, such as drought, light stress, extreme temperature, nutrient deficiency or pollution, on plant function (Jackson, 1986; Carter, 1991, 1993, 1994; Aldakheel and Danson, 1997). This can be directly related to the overall efficiency or health of a leaf's photochemical apparatus, which is impaired by stress (Krause and Weis, 1991; Ball et al., 1994). Damage caused by photoinhibition may be assessed by determining fluorescence and emission through chlorophyll a in plants treated with strong irradiation pulses. By measuring the emission of fluorescence, it has been found that photoinhibition is mainly observed in photosystem II (PS II) (Krause and Weis, 1991). This non-destructive technique has been a common approach for estimating PS II efficiency. Fluorescence indexes used for evaluating PS II functioning include: initial fluorescence (Fo), maximum fluorescence (Fm) variable fluorescence (Fv) and Fv/Fm ratio (Shole and Horton, 1993). Fv represents the difference between Fm and Fo (Fv = Fm-Fo). The Fo parameter is the minimal fluorescence yielded when all reaction centres are in the oxidized or open state. When leaves are briefly exposed to a saturating light level, all PS II centres are closed. That is, quinone A (QA) is reduced and a maximum yield of fluorescence (Fm) is observed. The Fv/Fm ratio, calculated as Fv/Fm=(Fm-Fo)/Fm, is a fluorescence variable directly correlated with the physiological efficiency of the photosynthetic machinery. This ratio is been considered to be proportional to the quantum efficiency of PS II (Bjorkman and Demming, 1987). In a wide number of plant species and ecotypes, an Fv/Fm ratio of 0.83 has been obtained in unstressed leaves. Hence, the effects of stressful environmental factors on PS II may be examined by determining the reduction in the Fv/Fm ratio (Ogren and Evans, 1992; Sholes and Horton, 1993). The yield parameter corresponds to Fv/Fm, but its value generally is lower than Fv/Fm.

The aim of this study was to determine chlorophyll fluorescence effect in apple tree with different rootstock leaves on different planting densities and training systems.

Materials and methods. Research was carried out with cultivar 'Auksis' on rootstocks P60 and P22 at the Lithuanian Institute of Horticulture in 2005.

Planting scheme of apple trees cv. 'Auksis' with rootstock P 60: 1 – spindle training system, planting density – 3 x 1.5 m (2222 trees per ha); 2 – slender spindle training system, planting density – 3 x 1.5 m (2222 trees per ha); 3 – free leader axis training system, planting density – 3 x 1.5 m (2222 trees per ha); 4 – spindle training system, planting density – 3 x 1.25 m (2667 trees per ha); 5 – slender spindle training system, planting density – 3 x 1.25 m (4444 trees per ha); 6 - spindle training system, planting density – 3 x 1 m (3333 trees per ha); 7- slender spindle training system, planting density – 3 x 1 m (3333 trees per ha); 8 – super spindle training system, planting density – 3 x 0.75 m (4444 trees per ha); 9 – slender spindle training system, planting density – 3 x 0.75 m (4444 trees per ha).

Planting scheme of apple tree cv. 'Auksis' on rootstock P 22: 1- spindle training system, planting density – 3 x 1 m (3333 trees per ha); 2 – slender spindle training system, planting density – 3 x 1 m; (3333 trees per ha); 3 – free leader axis training system, planting density – 3 x 1 m (3333 trees per ha); 4 – super spindle training system, planting density – 3 x 0.75 m (4444 trees per ha); 5 – slender spindle training system, planting density – 3 x 0.75 m (4444 trees per ha); 6 - spindle training system, planting density – 3 x 0.5 m (6667 trees per ha); 7- super spindle V form training system, planting density – 3 x 0.5 m (6667 trees per ha); 8 – slender spindle V form training system, planting density – 3 x 0.25 m (13333 trees per ha); 9 – super spindle training system, planting density – 3 x 0.25 m (13333 trees per ha); 10 - super spindle V form training system, planting density – 3 x 0.25 m (13333 trees per ha).

The measurements were performed on 5 plants from each apple tree cultivar. The fourth fully developed leaf from the east side of the tree was taken for analysis. The fluorescence was measured by a chlorophyll fluorometer PAM-210, Walz GmBH. The minimum (actual) fluorescence yield in light adapted sample (F_t) and maximum fluorescence yield (Fm) of illuminated light-adapted sample were measured with every saturation pulse 3500 μmol $m^{-2}s^{-1}$. Ft corresponds to the momentary value of fluorescence yield at a given actinic light intensity (85 μmol $m^{-2}s^{-1}$). Fm is defined as the maximum fluorescence yield of an illuminated sample induced by a saturation pulse. The maximum light-acclimated photochemical quantum yield of PSII (Y) was estimated according to the relationship $Y= (Fm'-Ft) : Fm' = ÄF : Fm'$ and the electron transport rate ETR = c x 0.5 x PAR x Y (Schreiber, 1995). Using this equation, it is assumed that 84% of the incident quanta are absorbed and 50% of the absorbed quanta are distributed to PS II.

Statistical calculations were performed by ANOVA for MS Excel vers. 3.43 (Duncan's Multiple Range t-test procedure, $P \leq 0.05$).

Results. The variation of investigated fluorescence parameters was determined by variable planting densities, tree forms and rootstocks.

Leaves of 'Auksis'/P 22 with spindle form were distinguished for substantially high minimum fluorescence (Ft) (Table 1). The most extensive Ft in super spindle form fruit trees was estimated in 3x1 m. planting system. Ft level notably dropped with reduction of orchard density. However, in case of highest density of fruit trees, Ft increased in super spindle and super spindle V forms apple tree leaves. With increase of planting density the level of minimum fluorescence of 'Auksis'/P 22 fruit trees with slender spindle fell down. The same tendencies were recognized in variations of maximum fluorescence (Fm). Differences were seen just in super spindle V form apple tree leaves, where Fm declined with growth of density of apple trees.

The quantum yield (Y) and rate of electron transport (ETR) in all kind of apple tree forms fell down with decrease of planting density. The most intensive quantum yield and electron transport were detected in super spindle V form apple tree leaves.

T a b l e 1. **Chlorophyll fluorescence parameters in leaves of apple tree cv. ‘Auksis’ on rootstock P 22**

1 l e n t e l ė. **Chlorofilų fluorescencijos rodikliai ‘Auksio’ veislės obelų su P 22 poskiepiu lapuose**

Different canopy form and densities combinations Skirtingi vainiko formos ir tankumo deriniai	Fluorescence parameters Fluorescencijos rodikliai			
	F_t	F_m'	Y	ETR
Spindle / Paprastoji verpstė, 3 x 1 m	0,230c*	0,625bcd	0,635a	16a
Slender spindle / Laiboji verpstė, 3 x 1 m	0,171ab	0,597abcd	0,710abc	17,93ab
Free leader axis / Laisvai augantis lyderinis vainikas, 3 x 1 m	0,164ab	0,560abcd	0,697abc	17,55ab
Super spindle / Superverpstė, 3 x 0,75 m	0,180abc	0,618bcd	0,719bc	17,6ab
Slender spindle / Laiboji verpstė, 3 x 0,75 m	0,1985bc	0,693d	0,705abc	17,78ab
Super spindle / Superverpstė, 3 x 0,5 m	0,147a	0,401a	0,653abc	16,44ab
Super spindle V form / V formos superverpstė, 3 x 0,5 m	0,156ab	0,607abcd	0,738c	18,6b
Slender spindle V form / V formos laiboji verpstė, 3 x 0,25 m	0,16ab	0,498abcd	0,680abc	17,175ab
Super spindle / Superverpstė, 3 x 0,25 m	0,155ab	0,463ab	0,655abc	16,5ab
Super spindle V form / V formos superverpstė, 3 x 0,25 m	0,164ab	0,549abcd	0,694abc	17,48ab

*Values, indicated by the same letters within the columns, are not statistically different at P≤0.05.
*Tomis pačiomis raidėmis skiltyse pažymėti skaičiai iš esmės nesiskiria (P≤0,05).

T a b l e 2. **Chlorophyll fluorescence parameters in leaves of apple tree cv. ‘Auksis’ on rootstock P 60**

2 l e n t e l ė. **Chlorofilų fluorescencijos rodikliai ‘Auksio’ veislės obelų su P 60 poskiepiu lapuose**

Different canopy form and densities combinations Skirtingi vainiko formos ir tankumo deriniai	Fluorescence parameters Fluorescencijos rodikliai			
	F_t	F_m'	Y	ETR
Spindle / Paprastoji verpstė, 3 x 1,5 m	0,173ab*	0,504abc	0,659abc	16,6abc
Slender spindle / Laiboji verpstė,3 x 1,5 m	0,184ab	0,585c	0,652abc	16,375abc
Free leader axis / Laisvai augantis lyderinis vainikas, 3 x 1,5 m	0,167ab	0,458 a	0,636abc	16ab
Spindle / Paprastoji verpstė, 3 x 1,25 m	0,166ab	0,503ab	0,559a	16,775abc
Slender spindle / Laiboji verpstė, 3 x 1,25 m	0,164ab	0,56b	0,710bc	17,773bc
Spindle / Paprastoji verpstė, 3 x 1 m	0,163ab	0,53ab	0,704bc	17,75bc
Slender spindle / Laiboji verpstė, 3 x 1 m	0,172ab	0,555ab	0,691abc	17,425abc
Super spindle / Superverpstė, 3 x 0,75 m	0,1855b	0,500ab	0,624abc	15,725a
Slender spindle / Laiboji verpstė, 3 x 0,75 m	0,163ab	0,579bc	0,719c	18,1c

*Values, indicated by the same letters within the columns, are not statistically different at P≤0.05.
*Tomis pačiomis raidėmis skiltyse pažymėti skaičiai iš esmės nesiskiria (P≤0,05).

Dissimilar results were in orchards on rootstock P 60. The minimum fluorescence in all apple tree forms declined with decrease of planting density. Highest Ft level was found in fruit trees with super spindle form. Largest Fm in spindle and slender spindle forms of fruit trees was detected in 3x1.5 m. planting system. Maximum fluorescence dropped with reduction of orchard density.

The quantum yield (Y) and rate of electron transport (ETR) in all apple tree forms fell down with decrease of planting density. However, when the fruit trees were planted most densely, the quantum yield and rate of electron transport in apple tree leaves increased. Highest rates of quantum yield and electron transport were detected in slender spindle apple tree leaves.

Discussion. In the reports of other researches it has been noticed, that the size of the productivity taken from one measurement was directly determined by the number of fruit trees, however, only to the corresponding bounds (Jackson et al., 1981; Mika, Pi¹tkowski, 1986). When the critical level was achieved, the intensity of photosynthesis in leaves dropped due to the effect of shadowing, made by the plants situated around (Wertheim et al., 1986). Correct orchard density and its appropriate care are needed in order to assure enough quantity and distribution of light (Stampar et al., 1998; Widmer, Krebs, 2001; Uselis, 2003).

Chlorophyll fluorescence analysis is a technique that provides information on the functioning and the adaptation of the photosynthetic apparatus to the different environmental conditions. The kinetics of chlorophyll fluorescence and the quantum yield are known to be indicative of the electron flow in photosystem II (PS II). This can be directly related to the overall efficiency or health of a leaf's photochemical apparatus, which is impaired by stress (Krause and Weis, 1991; Ball et al., 1994). The quantum yield parameter reflects the efficiency of PS II. ETR factor defines the fraction of incident light to be absorbed by the sample. Falling down of fluorescence parameters, which was due to the higher planting density, proves that the researched fruit trees experienced stress. It has been noticed in other studies as well, that enhanced competition concerning densities acts as a minor stress for photosynthetic system (Šabajevienė et al., 2005 and Šabajevienė et al., 2006). However, with every further enlargement of planting density the mentioned parameters were changing positively. That enables to conclude that the examined apple trees ('Auksis'/P 22 and 'Auksis'/P 60) experienced competitive stress.

Observed parameters of different rootstocks have been affected in a different way as well: growth of density positively influenced Ft and Fm in leaves of apple tree on rootstock P 22, and Y and ETR in leaves of apple tree on rootstock P 60. It shows that the fruit tree response within inter-competition depends on the type of rootstock.

The highest quantum yield and electron transport were detected in apple trees of super spindle V form and slender spindle V form. The open forms allow optimum light interception. This feature determines high photochemical efficiency in leaves. In the researches of other groups of scientists it has been established that the open forms with slender elements allow optimum light interception and generate good yields with high fruit quality (Widmer and Krebs, 2001).

Conclusions. 1. A fall down in fluorescence parameters due to the higher planting density proves that the investigated fruit trees experienced stress. The mentioned parameters were changing positively with every further enlargement of planting density. The examined apple trees ('Auksis'/P 22 and 'Auksis'/P 60) experienced competitive stress.

2. Distinct fluorescence parameters of different rootstocks show that the response of the fruit tree within inter-competition depends on the rootstock type.

3. The highest quantum yield and electron transport were detected in apple trees of super spindle V form and slender spindle V form.

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'AUKSIO' VEISLĖS OBELŲ SU P 22 IR P 60 POSKIEPIAIS CHLOROFILŲ FLUORESCENCINIŲ RODIKLIŲ TYRIMAI ĮVAIRIŲ KONSTRUKCIJŲ INTENSYVIUOSE SODUOSE

G. Šabajevienė, J. Sakalauskaitė, V. Šlapakauskas, N. Uselis, P. Duchovskis

Santrauka

2005 m. Lietuvos sodininkystės ir daržininkystės institute tirti fluorescenciniai rodikliai 'Auksio' veislės obelų su P 22 ir P 60 poskiepiais lapuose. Tirti vaismedžiai su laibosios verpstės, V formos laibosios verpstės, paprastosios verpstės, V formos superverpstės, superverpstės formų ir laisvai augančiais lyderiniais vainikais. Vaismedžiai su P 22 poskiepiu pasodinti 3 x 1,5 m; 3 x 1,25 m; 3 x 1 m ir 3 x 0,75 m tankumu, o vaismedžiai su P 60 poskiepiu – 3 x 1 m; 3 x 0,75 m; 3 x 0,5 m ir 3 x 0,25 m. Gauti rezultatai rodo, kad dėl tankumo kilusi didesnė medžių konkurencija veikia kaip stresas. Tačiau fluorescencinių rodiklių augimas tankiausiai pasodintų obelų lapuose rodo konkurencinės įtampos atsiradimą. Didžiausia kvantinė išeiga ir elektronų transportas nustatyti V formos superverpstės ir V formos laibosios verpstės vainikus turinčių vaismedžių lapuose. Tai rodo, kad atvira V forma užtikrina optimalų šviesos pasiskirstymo lygį, kuris lemia aukštą fotocheminį efektyvumą vaismedžių lapuose. Fluorescencinių rodiklių skirtumai obelų su skirtingais poskiepiais lapuose rodo, kad vaismedžių reakcija į tarpusavio konkurenciją priklauso ir nuo poskiepio.

Reikšminiai žodžiai: elektronų transportas, fluorescencija, kvantų išeiga, obelys, poskiepiai, sodo konstrukcija, tankumas.