UNIVERZITET U BEOGRADU
POLJOPRIVREDNI FAKULTET
Katedra za voćarstvo

INOVACIJE U VOĆARSTVU

VI savetovanje

Zbornik radova

Tema Savetovanja:

Upotreba bioregulatora u voćarstvu

Beograd,
02. februar 2017. godine

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Zbornik radova

Izdavač:
Poljoprivredni fakultet, Beograd
Katedra za voćarstvo

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Štampa:
Pekograf doo
Vojni put 258/d
11080 Beograd-Zemun

Tiraž:
330 primeraka

ISBN 978-86-7834-272-1

Sadržaj / *Content*

Uvodni referat

PRIMENA BILJNIH BIOREGULATORA KOD KONTINENTALNIH VRSTA VOĆAKA

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Izvod. Intenzivna proizvodnja voća, pre svega jabučastog i koštičavog, bez primene biljnih bioregulatora, koji su moćan alat za regulisanje brojnih fizioloških procesa u voćkama bi bila veoma teška. Najznačajniji bioregulatori su: α-naftil sirćetna kiselina (NAA), 6-benziladenin (BA), giberelini (GAs), etefon, aminoetoksivinilglicin (AVG) i 1-metilciklopropen (1-MCP). Oni se uspešno koriste u proizvodnji sadnica za popravku njihovog kvaliteta. U rodnim zasadima se koriste za regulisanje bujnosti i rodnosti stabala voćaka, kao i za popravku kvaliteta plodova. Mogu se primeniti i na ubranim plodovima radi povećanja njihove skladišne sposobnosti i smanjenja pojave fizioloških bolesti tokom čuvanja.

Ključne reči: NAA, BA, GAs, etefon, AVG, 1-MCP.

Uvod

Biljni bioregulatori (PBRs) ili biljni regulatori rasta (PGR) su hormoni ili hormonima slične supstance koje podstiču, inhibiraju ili utiču na biološke ili biohemijske procese u biljkama (Dussi, 2011). Njihovo korišćenje je moćan alat za intenzivnu proizvodnju voća. Biljni bioregulatori (PBRs) su otkriveni kao sredstva koja mogu poboljšati prinos, kvalitet i dugotrajnost plodova (Greene, 2010). Oni imaju jedinstvenu osobinu da u nekim slučajevima ista aktivna materija indukuje različit odgovor biljke u zavisnosti od vremena primene i korišćene koncentracije (Dussi, 2011). Rast i reproduktivni potencijal stabla se obično kontrolišu korišćenjem različitih hemijskih sredstava. U rasadničkoj proizvodnji se primenom PBRs podstiče razvoj prevremenih mladara na sadnicama, povećava se formiranje adventivnih žila i indukuje se opadanje lišća. Kod voćaka u punoj rodnosti primenom PBRs mogu se regulisati sledeće fiziološke reakcije: razvoj bočnih mladara; povećanje ili inhibiranje formiranja generativnih pupoljaka; regulisanje rodnosti pospešivanjem opadanja cvetova odnosno plodova; odlaganje opadanja plodova pred berbu; popravka opšteg izgleda ploda; popravka oblika ploda; kontrola vegetativnog rasta; povećanje zametanja plodova; povećanje obojenosti plodova; ubrzavanje ili odlaganje sazrevanja plodova; suzbijanje rasta vodopija; povećanje tolerancije na stres (Greene, 2010), kao i sprečavanje pojave rđaste prevlake na plodu. Efekat primene nekog

PBRs nikada se ne može posmatrati izolovano, bez razmatranja fiziološkog statusa biljke, navodnjavanja, mineralne ishrane, rezidbe, sistema ganjenja, prijema i distribucije svetlosti u kruni, kao i meteoroloških uslova koji vladaju u trenutku primene sredstva.

Primena bioregulatora u proizvodnji sadnica

Zasnivanje veoma intenzivnih zasada jabuke i kruške, a u poslednje vreme i trešnje zahteva velika finansijska ulaganja. Da bi se uložena stedstva što brže vratila, neophodno je obezbediti ranu rodnost (Theron et al., 2000; Wertheim et al., 2001), koja će ujedno kontrolisati i vegetativni rast stabla. Neophodno je da rodnost počne u drugoj godini i da se nastavi u godinama koje slede (Wertheim et al., 2000). Ranu rodnost je najlakše dobiti kada posađene sadnice poseduju veliki broj, više ili manje horizontalnih grana i ako se dobro razviju u prvoj godini posle sadnje (Wertheim et al., 2000; Hrotko et al., 2000; Yildirim i Kankaya, 2004;). Bočne grančice su mesto na kome se obrazuju prve kratke grančice sa generativnim pupoljcima, a ujedno su i prve grane za formiranje strukture stabla (Volz et al., 1994). Osim brže rodnosti velika prednost dobro razgranatih sadnica jabuke u odnosu na nerazgranate je i jednostavnije manipulisanje stablima u prvim godinama posle sadnje (Palmer i Warrington, 2000; Werth, 2003). Tokom eksploatacije, ovakve sadnice su produktivnije i zahtevaju manje radne snage za obrazovanje i negu stabala u zasadu (Van den Berg, 2003).

Za zasnivanje intenzivnih zasada jabuke, kruške, a u poslednje vreme i trešnje okalemljene na podlogama male bujnosti nabolje je koristiti sadnice koje imaju razvijene u što većem broju i dovoljno duge prevremene grančice koje su pozicionirane u zoni formiranja buduće krune voćke. Ovaj tip grančica se formira na aktivno rastućem mladaru iz letnjih pupoljaka. Međutim, kod većine voćnih vrsta bočni pupoljci na aktivno rastućim mladarima po pravilu ne daju prevremene grančice (Tromp, 1996). Aktivni vrh koji raste inhibira izrastanje mladara iz pazušnih pupoljaka istog mladara, i ta inhibicija se pripisuje, bar u delu, auksinu koji potiče iz vrha koji raste (Harris, 1975; Bubán, 2000; Wilson, 2000; Elfving i Visser, 2003; Neri et al., 2004). Da bi se bočni pupoljci na sadnicama aktivirali potrebno je da se savlada apikalna dominacija (Volz et al, 1994).

Mera koja se koristi za stimulisanje prirodne tendencije za formiranje prevremenih grana je višekratno uklanjanje mladih, nerazvijenih listova sa vrha rastućeg mladara (Werthaim et al., 2000; Bubán, 2000). Međutim, odstranjivanje mladih listića je dugotrajan i mukotrpan posao, a vrlo često i nedovoljno efikasan kod pojedinih sorti (Čmelik i Tojnko, 2005).

Jedan od najpouzdanijih načina za stimulisanje razvoja bočnih grana na aktivno rastućem mladaru je primena biljnih regulatora rastenja, čije korišćenje je obično efektivnije nego pinciranje centralne vođice nerazgranatih sadnica.

Utvrđeno je da regulatori rasta koji se ponašaju kao citokinini ili koji remete metabolizam auksina mogu da stimulišu razvoj bočnih mladara kada su primenjeni na stablima jabuke (Elfving, 1985). Danas se u rasadničkoj proizvodnji za savladavanje apikalne dominacije i stimulisanje razvoja lateralnih mladara na sadnicama jabuke najčešće koriste citokinini, kao što je benziladenin (BA), primenjen samostalno (Elfving, 1985; Volz et al., 1994; Hrotko et al., 2000; Neri et al., 2004) ili u kombinaciji sa giberelinima (GA) (Gudarowska & Szewczuk, 2004). Često korišćeni preparat za kontrolu apikalne dominacije i podsticanja razvoja prevremnih grančica je Promalin, koji predstavlja mešavinu jednakih koncentracija giberelina (GA_{4+7}) i citokinina (6-benzyladenine) u odnosu 1,8% : 1,8% (Wertheim i Estabrooks, 1994; Rossi et al., 2004; Čmelik i Tojnko, 2005; Radivojević et al., 2015). Uloga citokinina je da prekinu mirovanje letnjih pupoljaka i indukuju ćelijsku multiplikaciju, dok giberelini pospešuju izduživanje bočnih mladara (Hrotko et al., 2000; Rossi et al., 2004). Pomalin se koristi u koncentraciji 500-1500 mg l^{-1} (Rossi et al., 2004), a jedan litar rastvora je dovoljan za 100-200 sadnica jer se prska samo vrh sadnice (Van der Berg, 2002; Radivojević et al., 2016).

Osim vrste fitohormona i njegove koncentracije veoma je bitan i broj tretmana. Wertheim & Estabrooks (1994) navode da višekratna primena bioregulatora može indukovati jače formiranje prevremenih grančica na sadnicama jabuke nego ako je izvršena jednostruka primena. Višekratnom primenom preparata smanjuje se mogućnost interakcije između primenjenih hemijskih sredstava i spoljašnjih činilaca. Balkhoven-Baart et al. (2000) su utvrdili da je za sorte jabuke koje imaju teškoće u formiranju bočnih grana potrebno 4-6 prskanja sa 600 mg l^{-1} benziladenina, dok za sorte koje se jednostavno granaju 4-6 prskanja sa 300 mg l^{-1} benziladenina je dovoljno da se dobiju dobro razgranate sadnice.

Efikasnost primene ovih preparata je velika ne samo kod ’knip’ i jednogodišnjih, već i kod devetomesečnih sadnica jabuke (Radivojević et al., 2016).

Osim ovih regulatora može se koristiti i cyclanilide®, koji igra ulogu antiauksina u biljci (Elfving & Visser, 2006). On je registrovan u nekim državama SAD pod imenom Tiberon™ za indukciju prevremenih grančica na sadnicama jabuke, kruške i trešnje u koncentraciji 100 mg l^{-1} (Elvfing, 2010). On navodi da je jednokratna primena dovoljna za postizanje potrebnog broja prevremenih grančica na sadnicama.

Regulisanje rodnosti proređivanjem cvetova i plodova

Danas je, više nego ikad, na tršištu svežeg voća od presudnog značaja njegov kvalitet. Od mnogih reči koje opisuju kvalitet ploda najznačajniji su njegova veličina, spoljašnji izgled, karakterističan i svojstven ukus, i prijatna tekstura. Nedostatak bilo kog ključnog atributa kvaliteta ploda može umanjiti vrednost proizvoda (Looney, 1993). Zbog toga se proizvođači voća moraju fokusirati na primenu svih mera koje će zadovoljiti zahteve tržišta da bi konstantno proizvodili plodovi visokog kvaliteta u maksimalnoj količini (Link, 2000). Često je nemoguće dovesti do maksimuma sve parametre kvaliteta zbog pozitivne i negativne reakcije između njih, zbog toga mora biti uspostavljen odgovorno balansiran kompromis između kvaliteta i kvantiteta

(Link, 2000). Jedan od preduslova redovnog prinosa je adekvatan broj cvetova po stablu svake godine, a samim tim i dovoljno formiranih generativnih pupoljaka u prethodnoj godini. To se može postići samo kada ne postoji suviše veliki broj plodova po stablu. Plodovi, preko njihovih semenki negativno utiču na formiranje generativnih pupoljaka, tj. preko hormona stvorenih u njima.

U godini kada voćke formiraju daleko veći broj cvetnih pupoljaka/cvetova nego što im je potrebno za rodnost u tekućoj vegetaciji, a zametanje plodova bude dobro, formira se prekomeran broj plodova koji predstavlja veliko opterećenje za voćku. Konkurencija između plodova redukuje njihovu veličinu (Dussi et al., 2006), a negativno utiče i na druge osobine: boju, oblik, ukus, čvrstoću i trajašnost. Većina voćnih vrsta ima samoregulatorne mehanizme koji uslovljavaju osipanje plodova, pre svega slabih, malih ili plodova sa nedovoljnim brojem semenki (Costa, 2013; Greene & Costa, 2013). Opadanje nedozrelih plodova odvija se različitim intenzitetom u različitim periodima razvoja ploda i zavisi od genetičkih i ekoloških faktora. Prirodno osipanje dovodi do redukcije broja plodova na stablu, ali je u najvećem broju slučajeva nedovoljno da garantuje plodove koji veličinom i kvalitetom zadovoljavaju potrebe tržišta (Bregoli, 2007). Zbog toga je neophodno primeniti regulisanje rodnosti. Ono se postiže zimskom rezidbom i proređivanjem cvetova ili plodova, kao i sprečavanjem diferenciranja generativnih pupoljaka.

Zimska rezidba može se smatrati prvim korakom u kontroli rodnosti voćaka, kojom se uklanja određena količina rodnog drveta i time se uspostavlja odgovarajuća ravnoteža između vegetativnog rasta i rodnosti. Ona je kod jabuke, kruške i breskve nedovoljna za postizanje neophodnog kvaliteta ploda i redovne rodnosti, tako da je proređivanje plodova u cilju optimalnog opterećenja stabala plodovima neophodno (Bregoli, 2007). Kod breskve i nekatarine ručno proređivanje plodova je uobičajena tehnika koja se koristi, a osnovni razlog je nedostatak pouzdanosti hemijskih sredstava za proređivanje (Greene & Costa, 2013). Kod kajsije, šljive, trešnje i sorti višnje namenjenih konzumu u svežem stanju rezidba može predstavljati efikasan alat za postizanje željenog opterećenja rodom (Costa et al., 2013), mada u poslednje vreme i kod ovih voćnih vrsta zahtevi za povećanjem veličine ploda i kvaliteta povećali su interesovanje za proređivanjem ploda (Greene & Costa, 2013).

Proređivanje plodova kod jabučastih voćaka je od presudnog značaja za dobijanje plodova koji omogućavaju proizvođačima da ravnopravno učestvuju u međunarodnim marketima svežeg voća (Lopez, 2011). Ručno proređivanje koje se primenjuje kasno, posle junskog osipanja plodova, može omogućiti povećanje krupnoće plodova, ali ne i redukciju alternativne rodnosti (Maas, 2006). Pored toga ono se izvodi sporo i predstavlja skupu meru zbog upotrebe velikog broja radnika. Prihvatljivo je jedino ručno proređivanje koje ima korektivnu funkciju posle uspešnog hemijskog proređivanja, jer se njime uklanjaju plodovi koji ne mogu biti prva klasa, bez obzira na broj plodova na stablu (sitni plodovi, tamno-zeleni plodovi blizu centralne vođice, asimetrični plodovi ili na bilo koji način oštećeni plodovi). Zbog toga se hemijsko proređivanje smatra najefikasnijom metodom, s obzirom na to da je najisplativija, relativno brza, može biti urađena u najkritičnijem trenutku i ima najveći pozitivan efekat na diferenciranje generativnih pupoljaka (Greene & Costa, 2013).

Ovo je uobičajena tehnološka mera kod jabučastih voćaka. Hemijsko proređivanje je preduslov kod voćaka za 1) postizanje visokog kvaliteta plodova u smislu odgovarajuće krupnoće i obojenosti za prvu klasu, uključujući šećer (kao parametar ukusa) i dovoljnu čvrstoću (kao parametar za dobru trajašnost); 2) smanjenje potrebe za ručnim proređivanjem plodova; 3) savladavanje alternativne rodnosti (naizmenično smenjivanje godina sa malom i velikom rodnošću) obezbeđivanjem redovne umerene rodnosti (Costa et al, 2013; Greene & Costa, 2013). Za hemijsko proređivanje se mogu koristiti različite vrste hemikalija: đubriva, sredstva za zaštitu bilja, herbicidi i bioregulatori (Bound, 2010), koji pokazuju efikasnost ako se primene u cvetanju ili neposredno nakon zametanja plodova. Od korišćenih hemikalija se uvek traži da zadovolje potrebe voćara, potrošača i društva (Wertheim, 2000; Bregoli, 2007), posebno da nemaju štetno dejstvo na životnu sredinu. Uzimajući u obzir određenu gustinu stabala po ha, za svako stablo postoji optimalni broj plodova koji u berbi garantuje optimalnu veličinu ploda i maksimalni komercijalni prinos (Costa et al., 2013)

Najviše su u upotrebi sredstva koja pripadaju biljnim bioregulatorima. Upotrebom ovih sredstava pojačava se prirodni samoregulatori mehanizam osipanja plodova (Bangerth, 2000). Biljni bioregulatori mogu popraviti veličinu ploda, izgled ploda i unutrašnji kvalitet direktnim uticajem na rast i razvoj ploda i indirektnim preko regulisanja opterećena rodom, bujnosti stabla i arhitekture krune (Looney, 1993). Proređivanjem se delimično uklanja seme kao prirodni izvor giberelina, koji sprečavaju formiranje cvetnih pupoljaka (Dussi et al., 2006). Međutim, treba znati da rezultati ove mere su često nepredvidivi jer nekada mogu rezultirati nedovoljnom proređivanju, a nekada prekomernom proređivanju (Greene & Costa, 2013).

Rezultati primene bioregulatora kao sredstava za hemijsko proređivanje zavise od brojnih faktora: vrste, sorte, meteoroloških činioca, postojanja protivgradne mreže i dr. Variranje u efikasnosti hemijskih sredstava za proređivanje plodova između godina, kao i tokom godine čini ih veoma teškim za precizno predviđanje trenutka za hemijsku aplikaciju i očekivanu efikasnost proređivanja dobijenu st&ardnom dozom sredstava za proređivanje (Robinson i Lakso, 2004).

Svaka sorta jabuke i kruške zahteva korišćenje specifičnog programa proređivanja s obzirom na to da njihov odgovor može biti različit u zavisnosti od klimatskih činilaca i primenjenih tehnoloških mera.

Regulisanje rodnosti primenom biljnih bioregulatora se može izvršiti proređivanjem cvetova ili zametnutih plodova. Proređivanje cvetova je efektivna mera zato što smanjuje konkurenciju između cvetova i zametnutih plodova što je ranije moguće (Costa et al., 2013). Ovu meru proizvođači bi želeli da izbegnu zbog mogućeg prolećnog mraza, tako da se preporučuje kod sorti jabuke sklonih alternativnom rađanju (Fudži, Elstar, Zlatni delišes). Koštičave voćke, posebno breskva se najčešće proređuju u ovoj fazi. Od bioregulatora se koristi etefon, međutim on nije pouzdan, i njegova primena ne može postati rutinska mera zbog brojnih sporednih negativnih reakcija (Greene & Costa, 2013).

Proređivanje plodova se može izvršiti u relativno širokom vremenskom periodu. Normalan okvir je od cvetanja pa sve dok terminalni plodovi u cvasti ne postignu prečnik 16 mm (McArtney & Obermiller, 2012), odnosno 18 mm (Greene & Costa, 2013).

Efikasnost primenjenih sredstava uslovljena je različitim faktorima: vrsta, sorta, snaga stabla i potencijalni prinos, veličina ploda, vremenske prilike tokom, pre i posle primene sredstva, kao i metod aplikacije (koncentracija, količina vode, korišćenje adjuvanta) (Robinson i Lakso, 2004; Dussi, 2011).

Među sortama postoji velika razlika u odgovoru na hemijsko proređivanje plodova. Na primer kod jabuke postoje sorte koje su lake za proređivanje, dok su druge veoma teške, čak i kada se koriste različita hemijska sredstva ili njihova kombinacija (Costa et al., 2013).

Tako na primer proređivanje plodova kod sorte Fudži je veoma teško zato što ona ima visok stepen zametanja plodova i slabo prirodno osipanje (Belleggia et al, 2010). Sa druge strane sorte Greni Smit i Ajdared imaju izraženo veoma jako prirodno osipanje plodova.

Vremenske prilike umaju ključnu ulogu u reakciji voćke na hemijsko proređivanje (Greene & Costa, 2013), naročito temperatura, intenzitet svetlosti i vlažnost vazduha (Kolarič & Stopar, 2013). Veće osipanje plodova posle primene bioregulatora je povezano sa vremenskim prilikama koje favorizuju redukciju nivoa ugljenih hidrata u biljci, posebno nizak nivo svetlosti i povećana temperatura posle aplikacije sredstva (Fallahi & Greene, 2010). Temperatura posle BA primene je ključni faktor za dobijanje efikasnog proređivanja (Dussi et al., 2006).

Pored navedenih činilaca, opterećenje stabla rodom, broj listova na kratkim grančicama i broj semenki u plodovima takođe utiču na efikasnost proređivanja (Fallahi & Greene, 2010).

Robinson i Lakso (2004) preporučuju primenu NAA i BA kada je prečnik ploda 8-12 mm, a dnevne visoke temperature su iznad 21°C, a ne više od 26°C u narednih 4 dana posle primene. Izbegavati primenu kada je sunčeva svetlost tri dana pre i posle trenutka primene manja od 10 MJ m^{-2} dan^{-1} (oko 40% od pune osunčanosti). Temperatura u trenutku primene ne smatra se bitnom.

Bioregulatori kao sredstvo za proređivanje cvetova i plodova

NAA i NAAm

Sintetička sredstva na bazi Auksina (NAA i njegov amid NAAm) su prvo otkrivena sredstva za proređivanja plodova (Wertheim, 2000). Ove komponente su uključene u formiranje sloja za odvajanje i uslovljavaju opadanje preko aktivacije etilena, koji indukuje hidrolitičke enzime poligalacturonasu i celulasu, koje takođe povećavaju intenzitet disanja i smanjuju intenzitet fotosinteze (Bangerth, 2000;

Dennis, 2000). NAAm se primarno koristi kao sredstvo za proređivanje u periodu opadanja kruničnih listića. Koristi se u koncentraciji između 35 i 50 mg l^{-1} (Fallahi & Greene, 2010), a Wertheim (2000) navodi da koncentracija primene može biti i do 100 mg l^{-1}. NAAm je postalo alternativno sredstvo jer se sa NAA može izazvati prekomerno opadanje plodova (Dennis, 2000). Wertheim (2000) smatra NAAm mnogo pouzdanijim sredstvom od NAA.

NAA dobre rezultate postiže kada se primeni kasnije, oko 15 dana posle cvetanja, pri krupnoći plodova 10-15 mm (Lakso et al., 2001). NAA se koristi u koncentracijama od 2 do 20 mg l^{-1}, a u komercijalnim uslovima između 5 i 12 mg l^{-1} (Fallahi & Greene, 2010). Manje koncentracije mogu usloviti skroman efekat proređivanja, dok visoke koncentracije mogu izazvati prekomerno proređivanje ili redukovanje veličine ploda ili izostanak povećanja krupnoće ploda čak i kada je opterećenje rodom značajno smanjeno (Fallahi & Greene, 2010), posebno kod sorte crveni delišes (Dennis, 2000). Ovo je dobro poznata posledica stresa koji NAA uslovljava posle primene (Link, 2000; Dorigoni & Lezzer, 2007), jer NAA smanjuje intenzitet fotosinteze do 34%, u trajanju od 5 dana posle primene (Untiedt & Blanke, 2001). Prema Dennis (2000) u nekim uslovima NAA može usloviti formiranje veoma sitnih plodova (“pygmy” fruit). (Zbog velike zavisnosti od klimatskih činilaca NAA nikada nije korišćen u nekim klimatskim područjima (Wertheim, 2000).

Etefon

Etefon (2-chloroethylphosphonic acid) je sredstvo za proređivanje cvetova ili plodova, koje daje promenljive rezultate (Fallahi & Greene, 2010). U upotrebi je od 1969. godine. Njegovo dejstvo se zasniva na oslobađanju etilena tokom hidrolize unutar tretiranog tkiva (Dennis, 2000). Koristi se za proređivanje plodova kod jabuke, dok kod kruške nema smisla primenjivati ga zbog manjeg stepena oplođenja nego kod jabuke. Daje promenljive rezultate zato što njegovo dejstvo zavisi od faze razvoja cvetnog pupoljka/ cveta, odnosno veoma je visoko u fazi roze pupoljka, dok je u fazi precvetavanja skoro ravno nuli.

Vreme primene zavisi od sorte. Prskanje u fazi balona se najčešće primenjuje kod sorti koje imaju izrazitu sklonost ka alternativnom rađanju (Fudži, Elstar, Zlatni Delišes). Kod crvenog delišesa proređivanje može biti dobro posle primene u punom cvetanju. Etefon u koncentraciji od 300 mg l^{-1} primenjen na početku punog cvetanja postiže jak efekat kod sorte Elstar. Veće koncentracije (450–600 mg l^{-1}) su potrebne pri veoma jakom cvetanju, uz moguću opasnost od prekomernog proređivanja cvetova, tako da primena ovog regulatora zahteva visok stepen iskustva u proređivanju (Clever, 2007). Osim sorte i faze razvoja cveta na efikasnost utiče i temperatura, koja uslovljava stepen oslobađanja etilena u tkivu. Visoka temperatra posle primene može izazvati prekomerno opadanje plodova (Dennis, 2000). Intenzitet proređivanje raste linearno sa povećanjem temperature od 12 do 24°C.

Ovaj preparat može usporiti rast ploda. Pri koncentraciji 250-300 mg l^{-1} etefon je izazvao smanjenje broja plodova, koji su bili sitniji nego u kontrolnom tretmanu

(Link, 2000). Ponekad može izazvati i pojavu rđaste prevlake na plodovima (Clever, 2007)

Kod jabuke etefon se može koristiti i za proređivanje plodova. Aktivan je na početku junskog opadanja plodova kada je tendencija prirodnog opadanja visoka (Werthaim, 2000). On može biti koristan kao sredstvo sa visokim stepenom rizika pri krupnoći plodova od 20-25 mm, kada su ostala sredstva za proređivanje limitirana ili nemaju dobar efekat ili ne postoji druga održiva opcija proređivanja plodova (Fallahi & Greene, 2011). Kod sorte Zlatni delišes najveća osetljivost je pri krupnoći centralnog ploda 22-30 mm (Wertheim, 2000). Etefon u koncentraciji 400 ml l^{-1} efikasno proređuje sortu Zlatni delišes u fazi od 20 mm razvoja ploda. Plodovi počinju da opadaju 3 dana posle tretiranja etefonom, a dejstvo prestaje nakon 11 dana (Yuan, 2007).

Međutim njegovo dejstvo je teško predvidivo u ovoj fazi razvoja ploda. Visoka koncentarcija može izazvati totalno opadanje plodova, mada se to može dogoditi i sa malim koncentracijama (100–150 ml l^{-1}). Ovaj efekat proređivanja se može neutralisati prskanjem sa giberelinima. Primena etefona može dovesti do boljeg cvetanja sledeće godine kod jabuke, posebno zbog inhibitornog efekta na rast mladara.

Benzil adenin (BA)

Upotrebljava se od 1972. godine. Smatra se bezbednim sredstvom za korisne insekte, pre svega za pčele i prirodne neprijatelje grinja (Bound, 2006). Prvo je primenjivan u kombinaciji sa GA_{4+7} (Promalin ili Accel), a kasnije samostalno (Dennis, 2000). U kombinaciji sa GA_{4+7} je neefikasan kod sorti Fudži, Crveni i Zlatni delišes, dok je samostalno primenjen veoma efikasno i pouzdano sredstvo za proređivanje (Bound, 2006).

Mehanizam delovanja ovog sredstva je nedovoljno potvrđen. Yuan & Greene (2000) sugerišu da BA proređuje plodove preko redukcije sinteze ugljenih hidrata. Takođe povećana produkcija etilena može biti jedan od ključnih faktora, koji dovode do osipanja plodova (Dennis, 2000).

Pretpostavlja se da BA ispoljava efekat u proređivanju preko vegetativnog rasta. Kod ‘spur’ tipova Crvenog delišesa ima manju efikasnost zbog limitiranog vegetativnog rasta uslovljenog njegovom genetikom (Dal Cin et al., 2007).

Smatra se da je najbolji trenutak primene kada je prečnik plodova 10 mm (Wertheim, 2000; Yuan & Greene, 2000). Njegova uobičajena koncentracija primene je od 50 do 150 mg l^{-1} (Fallahi & Greene, 2010). Bregoli et al. (2007) su utvrdili da u toplijim uslovima Italije (Emilia-Romagna), kod sorte Gala BA ispoljava najbolji efekat kada je krupnoća plodova 10–12 mm, dok u hladnijim uslovima (Južni Tirol) pri krupnoći 14–16 mm. Zbog toga temperatura može biti mnogo značajniji faktor nego veličina ploda za određivanje momenta primene BA (Yuan & Greene, 2000; Maas, 2006; Clever, 2007).

Benziladenin (BA) može pokazati efikasnost u povećanju krupnoće ploda jabuke čak i u odsustvu proređivanja plodova (Stover et al., 2001) preko povećanja deobe ćelija (Wertheim, 2000).

Upešno se može koristiti kod kruške (Lopez et al., 2011). Za sortu Pakams trijumf, Bound & Mitchell (2002) su utvrdili da se najveći efekat postiže sa koncentracijom 100 to 150 mg l^{-1} primenjenom 11 do 26 dana posle punog cvetanja. Za soru Viljamovka najbolje je primeniti BA pri krupnoći plodova 10 to 15 mm u konentraciji 100 do 150 mg l^{-1} (Dussi, 2011; Dusi & Sugar, 2011).

Kombinovana primena preparata

Jedan od najvećih problema u primeni regulatora su promenljivi rezultati uslovljeni faktorima spoljašnje sredine i osobinama sorte. Najbolji način za redukciju varijabilnosti jeste kombinovanje hemikalija sa različitim mehanizmom delovanja ili njihovim korišćenjem jedan za drugim (Wertheim, 2000; Fallahi & Greene, 2010). Kombinacije se mogu primeniti same u razlitčitoj fazi razvoja ploda ili u isto vreme u tank miksu (Fallahi & Greene, 2010). Kombinacija dve ili više hemikalija (simultana ili sekvencijalna) preporučuje se za sorte koje su teške za proređivanje, jer kod njih hemijska sredstva primenjena samostalno nisu dovoljna za efikasno proređivanje (Dennis, 2000). Primena sredstava koja imaju različite mehanizme delovanja imaju za posledicu zadovoljavajući stepen proređivanja plodova (Fallahi & Greene, 2010). Proizvodi kao što su etrel, NAA i BA se često primenjuju u različitim kombinacijama i u različito vreme u periodu od 3-4 nedelje posle cvetanja kako bi se postiglo jače osipanje plodova nego kada se primene jednokratno (McArtney et al., 2012). Kombinacija NAA i BA može inibirati rast kod sorte Crveni delišes, mada kod drugih sorti ovakav efekat nije uočen (Link, 2000; Wertheim, 2000).

Novi preparati za proređivanje

Uvek se radi na dobijanju novih preparata sa boljim karakteristikama, posebno onih koji će imati manji uticaj na potrošače ili životnu sredinu. Mnogi, nekada korišćeni preparati su zabranjeni za upotrebu. Od regulatora rasta u novijim istraživanjima radi se sa ABA i ACC.

ABA je prirodni retardant rasta. Primena ABA u koncentraciji 500 mg$\cdot L^{-1}$ u punom cvetanju, opadanju kruničnih listića i pri krupnoći plodova 10-mm kod sorte kruške Viljamovka izaziva značajno proređivanje plodova, tako da su plodovi bili krupniji, čvršći i sa većim saržajem rastvorljive suve materije (Greene, 2012). Ono što je neprihvatljivo kod ove hemikalije je fitotoksični efekat, koji se manifestovao u pojavi žute boje lišća, kao i njegovog opadanja. Kod breskve, primena ovog sredstva u koncentraciji 250 mg$\cdot l^{-1}$ i 750 mg mg$\cdot l^{-1}$ (Giovanaz et al., 2015) pokazuje dobru efikasnost u proređivanju plodova. Međutim, BA primenjen nakon tretiranja sa ABA nije mogao da smanji pojavu žute boje lista i njegovo opadanje.

1-aminocyclopropane carboxylic acid (ACC) je prekursor etilena, koji se koristi kod jabuke za proređivanje plodova posle uobičajenog okvira proređivanja. Ovo je bitno za odloženo proređivanje, kada su plodovi krupnoće 18-30 mm u prečniku, obezbeđujući mogućnost proređivanja kada primarno proređivanje drugim sredstvima nije obezbedilo komercijalno prihvatljivi nivo prorede (McArtney & Obermiller, 2012).

Bioregulatori za sprečavanje diferenciranja generativnih pupoljaka

Giberelini mogu sprečiti diferenciranje generativnih pupoljka kod voćaka. Ova mogućnost može biti iskorišćenja za regulisanje rodnosti kod koštičavih voćaka, a u izvesnim situacijama i kod jabučastih. Kod breskve uobičajena proreda plodova se vrši ručno da bi se dobili plodovi tržišno prihvatljive krupnoće. S obzirom na to da je ručno proređivanje skupo i sporo, jedna od novijih strategija u regulisanju rodnosti je inhibiranje formiranja cvetnih pupoljaka. GA_3 primenjena 7, 10 i 13 nedelja posle punog cvetanja kod sorte breskve Redheven može smanjiti potrbu za ručnim proređivanjem od 40-90% (Coneva & Cline, 2006). GA_3 primenjena na početku diferenciranja generativnih pupoljaka (početak odrvenjavanja koštice) u koncentraciji 50-200 mg l^{-1} sa 1500-3000 L vode po ha značajno redukuje cvetanje kod breskve i nektarine naredne godine (do 50%) bez uticaja na visinu prinosa (Gonzalez-Rossia et al., 2007). Efekat redukcije cvetova je najveći u bazalnom delu letorasta i postepeno se smanjivao prema njegovom vrhu. Autori za područja gde postoji opasnost od pojave prolećnog mraza preporučiju kombinovanje GA_3 u koncentraciji 50-150 mg l^{-1} i dopunskog ručno proređivanja.

Za razliku od breskve, kod trešnje redukovanje rodnosti se obično vrši primenom zimske rezidbe. S obzirom na to da se danas najviše koriste podloge kontrolisane bujnosti, kao što je Gisela 5, koje podstiču produktivnost, a zahtevi tržišta za krupnim plodovima trešnje neprestano rastu javlja se potreba za dodatnim regulisanjem rodnosti i kod ove voćne vrste (Lang & Ophard, 2000). GA_3 primenjena u koncentraciji od 30 do 100 mg l^{-1} od kraja faze I (početak lignifikacije koštice, krupnoća ploda oko 13 mm) do kraja faze II (promena boje od zelene do slamasto žute, prečnik ploda oko 18 mm) redukuje broj generativnih pupoljaka na rodnoj grančici, ali ne smanjuje broj cvetova u jednom pupoljku. Redukcija je jača u osnovi jednogodišnjih grančica nego na majskim buketićima. Primenjena koncentracija ne utiče na visinu prinosa (Lenahan et al., 2006). GA_3 takođe usporava sazrevanje ploda trešnje u zavisnosti od primenjene koncentracije.

Kod jabuke se mogu primeniti giberelini kod sorti sklonih alternativnoj rodnosti u godini kada na stablima nema dovoljno plodova da bi se sprečilo preobilno cvetanje narednih godine. Za razliku od koštičavih voćaka, kod jabuke efikasnost GA_{4+7} veća je nego GA_3 u redukciji diferenciranja generativnih pupoljaka, kako na kratkim grančicama tako i na lateralnim pozicijama. Najbolje je primeniti tri puta (4, 6, i 8 nedelja posle cvetanja) u koncentraciji 100 mg l^{-1} (Devis, 2002)

Bioregulatori za sprečavanje opadanja plodova pred berbu

Neke sorte jabuke kao što su Jonagold, Crveni delišes, Ajdared, a u manjoj meri i Zlatni delišes, koje su ujedno i najznačajnije za gajenje u Srbiji, produkuju velike količine etilena i sklone su opadanju plodova neposredno pred berbu, pre nego što postignu optimalnu boju, zrelost i veličinu. Od regulatora rasta za sprečavanje ove nepovoljne pojave mogu se koristiti NAA, AVG i MCP.

Najstarije sredstvo koje se koristi za sprečvanje opadanje plodova je NAA. Jedna primena NAA može odložiti opadanje plodova 10-14 dana posle tretamana. Sa dve primene se odlaže period opadanja plodova. Međutim, pošto NAA pojačava produkciju etilena koji dovodi do omekšavanja plodova, što je obično pojačano sa dve aplikacije NAA ili toplim vremenom nakon prve primene (Yuan & Li, 2008).

Amino ethoxy vinyl glycine (AVG, trgovačko ime = Retain) je inhibitor ACC synthase, prvog koraka u sintezi etilena u plodovima (Lurie, 2010). Značajno smanjuje opadanje plodova pred berbu kod sorte Mekintoš (Robinson et al., 2010). On se može primeniti i kod koštičavih voćaka za sprečavanje opadanja plodova (breskva, nektarina i šljiva) što im omogućava da postignu krupnije plodove (Lurie, 2010). Kao sporedni negativni efekat redukovanja opadanja plodova izazvanih primenom AVG-a je odlaganje razvoja dopunske boje ploda, što se od strane brojnih proizvođača smatra velikim nedostatkom ovog sredstva (Robinson et al., 2006). Zbog toga se primenjuju manje koncentracije od preporučenih ili se vrši prskanje bliže normalnom datumu berbe da bi se eliminisao negativan uticaj na boju ploda, uz postizanje zadovoljavajuće kontrole opadanja plodova. Međutim, pojedinih godina AVG nepotpuno kontroliše opadanje plodova. To se dešava u toplim godinama kada u avgustu dnevne temperature prelaze 35°C, biljke doživljavaju stres i produkuju veću količinu etilena i formiraju sloj za odvajanje početkom ili sredinom avgusta. U tim godinama AVG primenjen u propisanoj koncentraciji i u određeno vreme može smanjiti, ali ne i u potpunosti zaustaviti opadanje plodova (Robinson et al., 2010).

Kombinacija AVG i NAA kontroliše osipanje plodova sorti Crveni delišes i Zlatni delišes bolje nego obe hemikalije pojedinačno (Yuan & Li, 2008). Slično je i kod sorte Mekintoš. Kombinacija AVG (822 $g \cdot ha^{-1}$) i NAA (20 $mg \cdot l^{-1}$) primenjena dve nedelje pre normalnog datuma berbe ima sinergistički efekat i može kontrolisati bolje opadanja plodova nego kada su obe supstance primenjene pojedinačno (Robinson et al., 2010)

Osim pojedinačne ili kombinovane primene AVG ili NAA za sprečavanje opadanja plodova se može koristiti posebna formulacija 1-MCP (Methylcyclopropene), namenjena za korišćenje u polju pre berbe (Yuan & Li, 2008). Primena 1-MCP redukuje sintezu etilena i usporava omekšavanje plodova nakon čuvanja. 1-MCP (160 ili 320 mg l^{-1}) i AVG (125 mg l^{-1}) + NAA (20 mg l^{-1}), kada se primene 15 dana pre planiranog termina berbe značajnije redukuju opadanje plodova od NAA ili AVG korišćenih pojedinačno, proširujući sezonu berbe plodova uz zadržavanje kvaliteta plodova (Yuan & Li, 2008). Između jednostruke i dvostruke primene 1-MCP ne postoji razlika u produkciji etilena, čvrstoći ploda i kontroli opadanja plodova (Yuan & Li, 2008). Primena 1-MCP u polju kod sorte kruške Viljamovka pokazuje istu efikasnost na sprečavanje opadanja plodova kao i NAA (Villalobos-Acuna et al., 2010). Čuvanjem ovakvih plodova u trajanju dužem od 3,5 meseci efekat primene se postepeno gubi.

Kod sorte jabuke Hanikrisp tretiranje sa 1-MCP (3,8% a.i.; Harvista; AgroFresh Inc., Spring House, PA) pre berbe u koncentraciji 160 mg l^{-1} uz utrošak vode od 1850 L ha^{-1} može se samnjiti učestalost pojave Soft skalda do 6 meseci u hladnjači, a zadržati dobra čvrstoća ploda (DeEll & Ehsani-Moghaddam, 2010).

Bioregulatori za poboljšanje kvaliteta plodova

Giberelinska kiselina se najčešće koristi za popravljanje oblika ploda kod voćaka jer izdužuje oblik ploda, smanjuje pojavu rđaste prevlake i utiče na razvoj partenokarpnih plodova (Looney, 1993). Rđasta prevlaka i pojava beličaste prevlake na pokožici ploda (scarf skin) su kozmetičke promene na plodovima pojedinih sorti jabuke koje su inicirane povredama u epidermalnom i hipodermalnom sloju ćelija u prvih 40 dana posle cvetanja. Ova oštećenja mogu izazvati velike ekonomske štete kod nekih sorti jabuke. Uobičajeno se primenjuje GA_{4+7} odmah nakon cvetanja da bi se umanjila jačina štete.

Trešnja tretirana sa GA_3 pokazuje manje rupičavosti, poremećaj koji se javlja posle iznošenja iz hladnjače, a uslovljen je ubojima napravljenim na plodovima tokom berbe. Kod nekih sorti trešnje primena GA_3 u koncenraciji 20 mg l^{-1} (početak faze II-odrvenjavanje koštice) usporava sazrevanje podova, smanjuje pucanje plodova zbog dejstva kiše, povećava masu ploda i sadržaj rastvorljive suve materije (Usenik et al., 2005).

Primena etefona kod sorte jabuke Jonagold (480 mg l^{-1} četiri nedelje pre očekivane berbe) podstiče razvoj antocijana, ali ne i drugih flavonoida ili hlorogenske kiseline. Sa druge strane, primena GA_3 (500 mg l^{-1} 17-19 nedelja posle punog cvetanja) usporava razvoj antocijana u pokožici ploda ove sorte (Awad & de Jager, 2002).

Bioregulatori za poboljšanje trajašnosti i skladišne sposobnosti voća

Jabuka kao sveže voće ima najveću potrošnju među kontinentalnim voćem tokom cele godine (Lu, 2012). Senzoričke osobine kao što su čvrstoća ploda, ukus i izgled su veoma značajni parametri kvaliteta, ali osim njih od velikog značaja je i sadržaj hranljivih komponenti.

Jedan od načina za produženje sezone čuvanja i prodaje plodova klimakteričnog voća, a najviše jabuke je primena odgovarajućih tehnologija čuvanja. Danas se koriste savremene hladnjače sa niskim sadržajem kiseonika (LO), veoma niskim sadržajem kiseonika (ULO) i najnoviji tip hladnjače je sa dinamički kontrolisanom atmosferom preko praćenje fluoroscencije hlorofila (DCA-CF). Ona sadrži ekstremno niski sadržaj kiseonika da bi se redukovalo disanje i odložilo dozrevanje plodova (Zanella & Rossi, 2015). Direktan efekat DCA-CF hladnjače je limitiran na period čuvanja unutar komore, dok efekat 1-MCP tretmana se može nastaviti i nakon vađenja plodova iz hladnjače (Zanella & Rossi, 2015). 1-MCP tretman može inhibirati sintezu isparljivih organskih komponenti redukujući aromu voća (Mattheis, 2008), dok je negativni sporedni efekat manje izražen na plodovima koji su izloženi čuvanju u DCA-CF

Drugi način koji se koristi za produžetak čuvanja i trajašnosti klimakteričnih plodova jeste primena bioregulatora koji inhibiraju aktivnost etilena. Methylcyclopropene (1-MCP) je osnova nove tehnologije čija primena se povećava da bi se popravio stepen čuvanja plodova posle berbe i održao njihov kvalitet. 1-MCP deluje preko preferencijalne interakcije sa receptorima etilena, tako da inhibira efekat kako endogenog tako i egzogenog etilena i tako uslovljava usporavanje procesa dozrevanja plodova i produkcije etilena u njima (Zanella & Rossi, 2015).

Koristni efekti 1-MCP preko usporavanje disanja i produkcije etilena ogledaju se u usporavaju dozrevanje plodova i ublažavanju nekih fizioloških bolesti koje se javljaju tokom dozrevanja, a izazvane su etilenom (Mattheis, 2008; Lu, 2012; Park, 2012). Ozbiljni fiziološki poremećaji na plodovima se mogu ispoljiti tokom čuvanja jabuka u hladnjačama, a površinski skald je jedan od glavnih oštećenja na plodovima sorte Greni smit. Skald ne zahvata meso ploda, a prepoznaje se kao prisustvo braon fleka nepravilne veličine na pokožici ploda. Plodovi sorti jabuke imaju veliku osetljivost na ovu pojavu, posebno kada su ubrani u nedozrelom stanju. Primena MCP u koncentarciji od 625-900 $\mu l\ l^{-1}$ sprečava pojavu skalda (Mogia et al., 2009; Tomic, et al., 2016). On deluje tako to što smanjuje sadržaj svih komponenti koje utiču na pojavu skalda: α-farnesene (AF), konjugovanih triena (CT) i ukupnih antioksidanata (AO), i povećava stabilnost ćelijske membrane (Mogia et al., 2010). Osim kod sorte Greni Smit MCP može smanjiti pojavu skalda i kod sorte Crveni delišes (Golding et al., 2005). Plodovi sorte Greni Smit tretirani sa 1-MCP se uspešno mogu čuvati i u hladnjačama sa normalnom atmosferom pri čemu zadržavaju dobre senzorne karakteristike u odnosu na plodove tretirane sa DPA ili netretirane plodove (Tomic et al., 2016).

Kod koštičavih voćaka efikasan je samo kod šljive, dok kod breskve i nektarine nije pokazao efikasnost (Lurie, 2010).

Bioregulatori za regulisanje bujnosti voćaka

Visokointenzivni sistem gajenja jabuke i kruške je polazna tačka modernog voćnjaka. Mala stabla koja ulaze u rodnost u drugoj godini nakon sadnje su osnovni preduslov za postizanje redovnog i visokog prinosa sa plodovima visokog kvaliteta uz smanjenje troškova berbe i rezidbe. Zato je veoma bitno u takvim voćnjacima držati bujnost pod kontrolom.

Prekomeran vegetativni rast dovodi do nedovoljnog prodora svetlosti u unutrašnost krune i redukovanja formiranja dopunske boje na plodovima, krupnoće ploda (Unrath, 1999), kontrole bolesti i štetočina (Miller & Tworkoski, 2003) i diferenciranja generativnih pupoljaka, posebno u donjoj polovini krune. Tome najviše doprinosi bujni porast mladara u vršnom delu krune u visokointenzivnim zasadima sa smanjenim rastojanjem između redova, a povećanom visinom stabla. Osim toga, ako postoji sistem protivgradne mreže, terminalni mladari, skloni su prorastanju kroz mrežu otežavajući i poskupljujući manipulaciju sa istom.

Potreba za dobijanjem visokih prinosa po jedinici površine sa krupnim plodovima često zahteva pojačano navodnjavanje i ishranu biogenim elementima, koji dodatno pojačavaju bujnost, bez obzira na to što su za zasnivanje ovih zasada korišćene slabo bujne podloge.

Za kontrolu bujnosti najbolje je koristiti nehemijske metode. Upotreba podloga male bujnosti i dobra rodnost omogućavaju najefikasniju kontrolu rasta stabla. Osim njih koriste se i druge tehnike koje sputavaju preveliki porast mladara u kruni. Glavna mera jeste zimska rezidba, koja osim kontrole rodnosti kontroliše i bujnost stabla. Takođe i letnja rezidba može smanjiti bujnost stabla. Pored njih mogu se primeniti i dodatne mere: rezidba korenovog sistema, zasecanje debla, postavljanje metalnih prstenova, savijanje grana i redukcija ishrane ili navodnjavanja. Ove mere mogu biti veoma skupe za izvođenje, a neke su i veoma rizične. Primenjene mere moraju biti usklađene sa karakteristikama sorti, koje u okviru određene voćne vrste pokazuju različite stepene bujnosti (Rademacher et al., 2004).

Upotreba bioregulatora za kontrolu bujnosti

Ponekad se moraju koristiti i hemijske mere koje se zasnivaju na upotrebi regulatora rasta. Oni se koriste u poslednjih nekoliko decenija. Svi PGR (chlormequat, daminozide i paclobutrazol) koji se koriste za regulisanje bujnosti, izuzev etefona, zasnivaju se na redukciji sinteze giberelina (GA) (Rademacher, 2000; Lurie, 2010). Upotreba najvećeg broja je zabranjena zbog toksičnosti (daminozid), odnosno velike količine rezidua (chlormequat chloride) koja je dovodila do kontaminacije zemljišta (Rademacher et al., 2004) i velike stabilnosti u biljkama (paklobutrazol). Korišćenje etefona, sredstva koje oslobađa etilen, kao retardanta rasta je moguće, ali može imati ograničeno korišćenje na rodnim stablima zato što u zahtevanim dozama za efektivnu kontrolu rasta stabla može izazvati značajno proređivanje plodova.

Novi regulator rasta prohexadione–calcium® - ProCa (BASF 125W) je registrovan za upotrebu kod jabuke i kruške u Severnoj Americi (Apogee) i Evropi (Regalis).

ProCa je takođe inhibitor biosinteze giberelina i ima karakteristike redukovanja rasta mladara (Unrath, 1999). On redukuje GA_1 nivo (aktivni giberelin) i povećava koncentraciju njegovog prekursora GA_{20} (neaktivni giberelin). Koristi se za folijarno tretiranje. Ne poseduje rezidualne efekte na voćkama (Rademacher et al., 2004). Smatra se bezbednom hemikalijom jer se koristi u maloj koncentraciji, vrlo brzo se razlaže (ograničena postojanost), tako da on ne predstavlja opasnost za potrošača i životnu sredinu.

Upotrebom ovog regulatora rasta smanjenje rasta mladara može biti veće od 40%. Redukovan rast mladara uslovljen je skraćivanjem internodija, a ne smanjenjem broja nodusa **(**Bubán et al., 2004). Kod jabuke su se pokazale kao mnogo efikasnije višekratne primene ProCa u malim koncentracijama nego jednokratna primena (Unrath, 1999). Prvo prskanje se primenjuje jednom kada mladari počnu da rastu i drugi put tokom sezone rasta, na početku novog porasta mladara. Drugo prskanje je obično potrebno da bi se izbegao ponovni rast mladara (Medjdoub et al., 2004).

Odgovor na jednokratnu primenu traje 3-4 nedelje, tako da višekratne primene treba vršiti na 2-3 nedelje (Unrath, 1999). Ako su doze primene ispod 125 mg l^{-1} tokom perioda osetljivog za zametanje plodova (opadanje kruničnih listića pa sve do 14 dana posle opadanja kruničnih listića) kvalitet plodova nije ugrožen (Unrath, 1999). Primena ProCa kod nekih sorti kruške u koncentraciji 50-250 mg l^{-1} primenjena jednom do tri puta redukuje rast mladara kod svih sorti (Smit et al., 2005).

Sporedno pozitivno dejstvo primene prohexadione–calcium (ProCa)

McArtney et al. (2006) su utvrdili sinergistički efekat ProCa sa GA_{4+7} protiv pojavljivanja beličaste prevlake na pokožici ploda (“scarf skin”) kod sorte Gala. Prohexadione–calcium (250 mg l^{-1}) primenjen dva dana posle prvog tretmanom GA_{4+7} u koncentraciji 20 mg l^{-1} (od ukupno tri tretmana) može značajno više smanjiti intenzitet pojave beličaste prevlake na pokožici ploda nego samostalna primena oba preparata. Ovi autori smatraju da ProCa, inhibirajući enzim dioksigenazu zavisnu od 2–oksoglutarične kiseline, rezultira povećanjem nivoa endogene GA_4 i redukuje smanjenje nivoa GA_4 i GA_7, koje su dodate egzogeno.

ProCa kod nekih sorti jabuke povećava zametanje plodova kada se primeni u trenutku opadanja kruničnih listića u početnoj dozi od 125-250 mg l^{-1} (Greene, 2007). Njegova primena može smanjiti pojavu bakteriozne plamenjače kod jabuke i kruške (Bubán et al., 2004), ali u koncentracijama većim od 250 mg l^{-1}. Kod kruške sekundarno cvetanje može biti značajno smanjeno primenom ProCa, čak i do 80% (Costa et al., 2001). Sekundarni cvetovi su često mesto prodora bakterije *Erwinia amylovora,* koja izaziva pojavu bakteriozne plamenjače (Rademacher et al., 2004).

Tri tretmana sa ProCa sorte Krips pink u koncentracijama od 500 i 750 mg l^{-1} izvedena 3, 33 i 63 dana posle punog cvetanja značajno povećava procenat crvene boje na plodovima (Wan Zaliha & Singh, 2013).

Sporedno negativno dejstvo primene prohexadione–calcium (ProCa)

Uticaj na zametanje i krupnoću plodova i diferenciranje generativnih pupoljaka je često kontradiktoran. Tretmani sa ProCa ne utiču negativno na zametanje plodova i diferenciranje generativnih pupoljaka (Bubán et al., 2004; Medjdoub et al., 2004; Asin et al., 2007). Međutim, drugi autori navode da kod nekih sorti jabuke i kruške ProCa može smanjiti krupnoću ploda, kao i diferenciranje generativnih pupoljaka (Smit et al., 2005). Prohexadion–calcium primenjen u koncentraciji 250 mg l^{-1} redukuje veličinu ploda sorte Gala (McArtney et al., 2006), a može redukovati i veličinu ploda kod nekih sorti kruške (Viljamovka, Boskova bočica), što ne mora uvek biti povezano sa povećanim opterećenjem rodom (Sugar et al., 2004; Greene, 2007). Strategije regulisanja bujnosti koje uključuju manje doze ProCa mogu redukovati ili potpuno eliminisati njegov negativan efekat na krupnoću plodova (Greene, 2007; Asin et al., 2008). Najčešće se preporučuje njegovo kombinovanje sa rezidbom korenovog sistema (Maas, 2008).

Kod nekih sorti jabuke čiji su plodovi skloni pucanju pokožice (‘Stayman’) prskanje stabala u cilju redukovanja bujnosti sa ProCa može pojačati ovu pojavu. Ona se može smanjiti tretiranjem plodova sa GA_{4+7} nakon primene ProCa, ali ne u potpunosti (Miller, 2007).

Bioregulatori registrovani za primenu u Srbiji

Spisak bioregulatora čija primena je dozvoljena u proizvodnji voća u Srbiji nalaze se na listi registrovanih sredstava za zaštitu bilja. Registrovani bioregulatori su prikazani u tabeli 1.

Tabela 1. Lista registrovanih sredstava za zaštitu bilja (26.01.2016).

Ime	Aktivna supstanca		Proizvođač	Rešenje o registraciji važi do:
	Naziv	Sadržaj		
HEMIJSKA SREDSTVA ZA ZAŠTITU BILJA – REGULATORI RASTA				
Regalis	proheksadion-kalcijum	100 g/kg	BASF SE, Deutschl&	01.07.2018
Regalis plus	proheksadion-kalcijum	100 g/kg	BASF SE, Deutschl&	31.12.2021.
BIOPESTICIDI – REGULATORI RASTA (BIOHEMIJSKI)				
Smartfresh	1-metilciklopropen	33 g/kg	Rohm & Haas, USA	29.07.2023
Gibb plus	giberelin GA4 i GA7	10 g/l	Globachem, Belgium	09.03.2025
Gibbalin	giberelin GA4 i GA7 + 6-benziladenin	19 + 19 g/l	Globachem, Belgium	28.08.2023
Globaryll 100	6-benziladenin	100 g/l	Globachem, Belgium	15.07.2023
Kelpak	ekstrakt morske alge (Auksini +Citokinini)	10,7+0,03 mg/l	Kelp Products, South Africa	31.12.2019

Iz tabele 1 se vidi da sredstva koja sadrže etefon, NAA ili NAAm, AVG i 1-MCP (namenjen za tretiranje plodova pre berbe) nisu registrovana. Da bi se proizvođačima obezbedila veća mogućnost regulisanja brojnih fizioloških procesa u biljkama poželjno je registrovati sva sredstva čija upotreba nije zabranjena u zemljama Evropske unije, pre svega u onim članicama koje imaju slične klimatske uslove kao Srbija. Na taj način proizvodnja voća bi se intenzivirala, a proizvedeno voće bi svojim kvalitetom moglo da izdrži konkurenciju na svetskom tržištu voća.

Zaključak

Za kontrolisanje brojnih fizioloških procesa kod kontinentalnh vrsta voćaka, voćarima na raspolaganju stoje bioregulatori koji se smatraju bezbednim za upotrebu. Jedan broj njih je registrovan za primenu i u Srbiji, a neophodna je registracija i drugih bioregulatora koji su značajni za proizvodnju voća. Ove komponente mogu imati veliki efekat na visinu prinosa i kvalitet proizvedenih plodova, kao i na njihovo ponašanje nakon berbe. Proizvođači treba da budu svesni da mnogi bioregulatori, bilo da su primenjeni u proizvodnji sadnica, proizvodnji plodova i na ubranim plodovima mogu imati korisne efekte ako su pravilno upotrebljeni. Nestručna primena u smislu koncentracije, načina i vremena primene, meteoroloških uslova i bioloških osobina vrste, odnosno sorte može imati nesagledive posledice po ekonomičnost proizvodnje.

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The Use of Plant Bioregulators in Deciduous Fruit Trees

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Summary

Intensive fruit production, primarily pome and stone fruits, without the use of plant bioregulators, which are a powerful tool for the regulation of many physiological processes in fruit trees, would be very difficult. The most important bioregulators are as follows: α-Naphthaleneacetic acid (NAA), 6-Benzyladenine (BA), Giberellins (GAs), Etefon, Amino ethoxy vinyl glycine (AVG) and 1-Methylcyclopropene (1-MCP). They are successfully used in the production of nursery trees in order to improve their quality. These compounds are also used for regulation of fruit trees vigor and productivity as well as for improving fruit quality. In addition to this, bioregulators can be applied on harvested fruits to increase their storage ability and reduce the incidence of physiological diseases during storage.

Key words: NAA, BA, GAs, etephon, AVG, 1-MCP.

Invited lecture

PHOTOSYNTHESIS INHIBITION AS A TOOL FOR APPLE FRUITLET THINNING

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Abstract. The possible mechanisms of apple fruitlet abscission are presented in this paper. Prevailing hypothesis on hormonal triggered processes in the event of “correlative dominance effects” of adjacent fruitlets or nearby shoot tips has the opponent theory of assimilate supply dependent fruitlet abscission. Assimilation shortage may also be involved in the correlative auxin processes but the connections of both statements are not clear yet. On last years a lot of evidence is provided in support of assimilation dependent fruitlet abscission process. At the time just after the end of the flowering, a strong competition between fruitlets and shoots for photosynthates exist. Shading experiments comparable for a few days of cloudy weather provoked strong natural apple fruitlet abscission. If the applications of chemical thinners are followed by a few days of shading, much stronger abscission occurs comparing to thinner applications without shade. A photosynthesis inhibitor metamitron has gone into registration for fruitlet thinning purpose and is available in Europe last year. A good thinning results can be achieved up to 14 mm king fruit diameter, but additional studies should be made to adapt dosage for the present and predicted light intensity at the time just after metamitron application.

Keywords: apple fruit, shading, metamitron, thinning agents, photosynthesis.

Introduction

Apple production is based on regular, annual crops of high internal and external fruit quality. Frequently, apple fruit trees form too many flowers and set too many fruit to obtain high quality and regular marketable crops throughout the year. The main problem of too high fruit set is abundant yield of low quality fruits. Secondly, one of the biggest problems of high yielding apple and pear orchards is alternate bearing phenomenon. A prerequisite for an annual crop is an adequate initiation of flower bud formation, which can only be achieved when there are not too many fruitlets per tree. The chemical thinning of flowers or fruitlets is actually the only way to avoid alternate bearing and to improve fruit appearance. Thinning of flowers or fruitlets improves fruit appearance and return bloom and has become a standard practice in the growing of many fruit crops (Greene and Costa, 2013). Chemical thinning has been regarded as the most satisfactory method of thinning since it is the most cost-effective and it is relatively fast so it can be done at critical times and has the greatest positive effect on return bloom. For this reason, the chemical thinning practice has been customary in intensive apple production for 40 years and more (Costa *et al*., 2005).

Several chemical thinners are currently available, but not all may remain on the market or be used in specific circumstances. Basically two approaches to fruit set reduction are used: flower thinning and fruitlet thinning. Flower thinning is not popular with growers, because they are reluctant to eliminate a proportion of the flowers prior to ensuring adequate fruit set. However, in the case of cultivars that annually set abundantly or in the case of favourable climatic conditions for fruit set, flower thinning is the standard practice. In this case later fruitlet thinning is insufficient to reduce fruit set adequately (Wertheim and Webster, 2005). Chemical flower thinning is performed with caustic compounds which make the injury to the generative organs in the flowers (also are called pollinicides). One of the first flowers thinner was sodium-dinitro-ortho cresylate (DNOC) which remained an important blossom thinner for arid regions until 1990 when registration ceased. After then wide search for the new bloom thinners has been activated and continuous even today. In Europe ammonium thiosulphate (ATS) is the most evaluated and used blossom thinning agent on apples. Beside ATS, hydrogen cyanamide (Dormex), endothalic acid (Endothal) or sulfcarbamide (Wilthin) were more or less successfully used on apples or on stone fruit (Fallahi *et al*., 1998; Fallahi and Williemsen, 2002). Many other desiccating chemicals have been researched but most have been unsuccessful because of lack of thinning at low concentration or phytotoxic side effect at higher concentration. Lime sulphur, sodium chloride, potassium bicarbonate and fish or plant oils was found to effectively thinned apples if applied to full bloom at concentration lower than 3% (Bound, 2010; Stopar, 2004).

Much more interesting for the growers is the use of fruitlet thinners. They can be used from post-bloom period up to 20 mm fruitlet diameter. In the world market we could find following traditional apple fruitlet thinning compounds: naphthaleneacetamid (NAD), 1-naphthaleneacetic acid (NAA), ethephon, 6-benzyladenine (BA) and carbaryl. In the last year’s carbaryl disappeared from many countries, including all European states, because of ecological and toxicological reasons, high persistency and toxicity for the bees. The main problem of all these compounds is the inconsistency of the thinning action and/or unpredictable thinning results. Beside tree condition (age, vigour, bloom density, stress, etc.) and cultivar characteristics, weather condition can strongly affect thinning response of individual tree (Dennis, 2000; Wertheim and Webster, 2005; Williams, 1994). Also some negative effects of thinners on fruit size were found. Higher concentration of NAA may over-thin or reduce fruit size on some cultivars as ‘Delicious’ or ‘Fuji’, or not increase fruit size even though crop load is substantially reduced (Stopar and Tojnko, 2005). NAD should not be used on ‘Delicious’ because of high percentage of pygmy fruit can happen (Williams and Edgerton, 1981). Pygmy fruit can be the result when NAA + BA are combined for thinning some apple cultivars as ‘Delicious’ (Bukovac *et al*., 1994). These are the reasons for searching the new thinning compounds. Thinning properties of abscisic acid (ABA) was proved on apples and pears and the most effective time of application was found at 10 mm fruitlet diameter (Greene *et al*., 2011). Aminocyclopropane-1-carboxylic acid (ACC) is the new, promising but not yet registered thinning agent (Greene and Costa, 2013). The new thinning agent already registered on all European countries and waiting for registration in US is the photosynthetic inhibitor metamitron. Metamitron has been reported to be quite active as a thinning agent for pome-fruits, mainly for apple and pear (McArtney and Obermiller, 2012).

The theory of apple fruitlet abscission

Shortly after flowering non-pollinated or non-fertilized ovaries, which were grown only minimally, are shed in the so called “first drop”. A week or two later the second drop start to begin and this drop is called “June drop”. Second drop can be done in one or more waves, mostly at about 8-12 mm fruitlet diameter (middle of May), and after that, not necessarily, in the start of June or later to the end of June. The last theoretically distinctive drop is the drop of fruit before harvest, where the premature full-grown fruit shed in so called “preharvest drop”.

In the case of leaves the abscission is an event repressed by auxin and activated by ethylene or is controlled by an “auxin-ethylene balance”, i.e. the relative concentrations of auxin and ethylene in the abscission zone determine to which side the balance between abscission or retention tips (Osborne, 1989; Sexton, 1997). If tips towards the ethylene side, the cell-wall break down in the leaf petiole abscission layer occurs and abscission follows. If the balance tips towards the auxin side, no breakdown or abscission of leaves occurs. Senescence, darkness, drought, wounding and the presence of abscisic acid increase the ethylene supply. Some of these factors reduce auxin supply as well such as low light conditions or wounding. Active growth is the main factors which increase auxin supply (Tromp and Wertheim, 2005).

The drop of young fruitlets is more complicated than the described above for the leaves, and is so called “correlatively triggered” abscission. According to this hypothesis, put forward by Bangerth (2000), young fruitlets senescence only starts after their drop is already decided by a correlative event. In fruitlets that are destined to shed, auxin export seems to have been reduced to a lower level by “correlative dominance effects” of adjacent fruitlets or nearby shoot tips. In the phenomenon called “primigenic dominance” the fruitlet which set first dominate above later set fruitlets (Bangerth, 1989). Fruitlets which set later (the dominated fruitlets) or the fruitlets near the growing shoot tips show a lower auxin export and a reduced growth rate. The explanation is that although dominating or dominated fruitlets and shoot tips all export auxins, at junctions where the auxin streams meet, the stronger polar auxin transport (mostly from dominating fruitlet or shoot tip) inhibits weaker one (from dominated organs). This causes an auto-inhibition of auxin production in the dominated organs. Possibly the cytokinin synthesis of the dominated fruitlet is reduced as well, which would further affect fruitlet growth negatively. The overall result is that the auxin transport through the abscission zones of many weak fruitlets is increasingly reduced until a point at which abscission is inevitable. Ethylene is needed for the final step in this process, the induction of necessary enzymes for cell-wall break down. Also should be noted that polar auxin transport from a fruitlet is essential for an adequate vascular tissue differentiation in pedicel. A good vascular connection allows adequate supply of water, minerals and assimilates to the fruit, and also allows further polar auxin transport itself, by feedback auxins stimulates its own transport, synthesis and/or concentrations. Moreover, organs with a high auxin-diffusion rate have a direct attractive effect on assimilation transport (Bangerth, 1989).

The dominance of one fruitlet over another depends on time of fruitlet set, on seed number and number of fruitlets per cluster. The first set fruitlet, also in the dominant position in the flower cluster (known as king fruit), show stronger auxin transport comparing to lateral set fruitlets. The dominance of shoot tips over neighbouring fruitlets in the cluster depends of their proximity and vigour (Tromp and Wertheim, 2005).

Assimilation shortage may also be involved in the correlative auxin processes. It has been observed that NAA, NAAm or ethephon reduce leaf net-photosynthesis, just at a time when leaf area is small and fruitlets and shoots growing away rapidly. The combination of a reduced auxin transport from dominated fruitlets by correlative inhibition plus assimilates deficiencies leads to the formation of stress ethylene, which in turns induces abscission (Untiedt and Blanke, 2001). Further, some fruit growing practices as girdling, using growth retardants or dwarfing rootstock, bending of shots reduce the degree of fruitlet shedding, and at the same time reduce shoot growth. Retarded shoots have more surplus of assimilates and lack of competition for carbohydrates do not push fruitlets into abscission – is one story. Also at the same time retarded shoot do no export a lot of auxins from growing tips (which stop to grow) and would not present dominating auxin streams from shoot tips, and fruitlets would persist in the cluster – is the second story. Both stories can be coupled by correlative inhibition effect where auxin export is the primary signal, but it is difficult to completely rule out temporary carbohydrate shortage as a main (independent) factor of fruitlet abscission.

Possible mode of action of main thinning agents

Most thinning agents are effective only when applied prior to the period of June drop, when fruitlets abscission is occurring spontaneously. Fruitlet abscission is not accompanied with leaf abscission, nor do thinning agents induce leaf abscission when applied at this time. These facts suggest that chemicals only stimulate the process of natural abscission and fruit and leaf abscission are regulated by different processes, at least during this early period of fruit development (Denis, 2002).

NAA was the first chemical to be used extensively for thinning; hence more work has been done with NAA than with any other chemicals. Several mechanisms were proposed to explain the thinning action of NAA. Luckwill (1953) noting that seed abortion was common in fruitlets sprayed with NAA, proposed that this response reduced the ability of some fruits to compete for nutrients, leading to abscission. Other researchers found that NAA can thin several cultivars without affecting seed number (Batjer and Thompson, 1961). Eberth and Banghert (1982) presented data indicating that NAA reduces auxin synthesis and transport from the fruit to the abscission zone. They measured extractable and diffusible auxin content of apple fruitlets following application of carbaryl, ethephon and NAAm. They concluded that reduced auxin transport was the major factor responsible for the thinning action of all three compounds, but the inconsistencies in their data make the conclusion questionable. Auxin applications stimulate ethylene production in many plant tissues, and this increase in the concentration of ethylene could induce abscission. When Ebert and Bangerth (1982) compared the effect of three thinning agents (see above) on apple fruitlet abscission they found high ethylene evolution after ethephon treatment, while NAAm provoked a weak ethylene response, whereas carbaryl had none. They concluded that ethylene evolution of itself was not sufficient to induce abscission. The possible effect of NAA in inhibiting photosynthesis will be discussed in next chapter.

BA has been used as a thinner shorter time than NAA, and therefore its mechanism of action has not been studied extensively. Application of BA stimulated ethylene production in both leaves and fruits and the rate of evolution increased with the concentration applied (Greene *et al*., 1992). The thinning response did not follow ethylene evolution and they concluded that BA might reduce the supply of sugar to the fruit. Yuan and Greene (2000) observed stimulation of dark respiration after BA application and put a hypothesis that reduced carbohydrate supply to the fruitlets leading to its abscission.

Ethephon is an old well known compound which hydrolysed in tissue and release ethylene. After than the fruitlet abscission occurs, before and at the time of June drop or at harvest time. Thus, a logical hypothesis that fruit thinning agents (as NAA, BA, ethephon) stimulate ethylene evolution and this is the base for fruitlet abscission. But only when ethephon was used the ethylene evolution increased dramatically; other agents had little effect on ethylene evolution, carbaryl had none and thinning response did not parallel fruit ethylene content. This suggests that ethylene is not the primary factor controlling fruitlet abscission.

The mode of action of three new thinning compounds also does not give equal answer for the main reason of starting the fruitlet abscission process:

Thinning properties of abscisic acid (ABA) was proved on apples and pears and the most effective time of application is at 10 mm fruitlet diameter (Greene *et al*, 2011). ABA is a naturally occurring hormone which has the key function in the regulation of stomata movement. Closing the stomata, thus reducing photosynthesis and restricting carbohydrate supply should be the important factor contributing to fruitlet abscission.

Aminocyclopropane-1-carboxylic acid (ACC) is the new, promising but not yet registered thinning agent where reports exist on successful thinning of pome and stone fruits. ACC is the natural occurring compound presenting one of the last steps in ethylene biosynthetic pathway. Application of ACC results in rapid evolution of ethylene and this may be the mode of action of this thinner. A consistent results coming from apple thinning experiments while on plums and pear trials variable thinning is reported (Greene and Costa, 2013).

Metamitron (Brevis) is the photosynthetic inhibitor, originally herbicide functioning through inhibition of photosystem II where blocking the electron transport and chlorophyll fluorescence is enhanced. Metamitron has been reported to be quite active as a thinning agent for pome-fruits, mainly for apple and pear (McArtney and Obermiller, 2012). The phytotoxicity occurred on some leaves but the effect is only temporary and does not influence fruit finish.

Photosynthesis inhibition and fruitlet thinning

On last year’s more and more evidence is provided in support of assimilation-dependent fruitlet abscission process. Even a small reduction of photosynthate translocation to the fruitlet can cause its abscission (Schumacher *et al.*, 1987). Canopy light interception reduced to 60-90% of full sunlight throughout a year can cause significant apple fruitlet abscission (Doud and Ferree, 1980). Byers *et al.* (1986, 1990, 1991) showed that reducing light interception by 90% when fruitlets were 8-33 mm in diameter caused dramatic fruitlet abscission, similar to the application of photosynthetic inhibitors. They found that after 3 day of artificial shade fruit stopped growing and dropped 7-12 days later. They suggested that thinning chemical may interfere with photosynthesis leading to a deficiency of carbohydrates. When shading is followed by chemical thinning, fruitlet abscission can be excessive (Lehman *et al*, 1987). Stopar *et al.* (1997) found that NAA application inhibited carbon assimilation by as much as 25% in ‘Delicious’ and ‘Empire’ leaves and some inhibition was evident for as long as 2 weeks. In the same experiment Stopar *et al.* (1997) did not find negative influence of BA on net photosynthesis. However, Yuan and Green (2000) reported that net photosynthesis was reduced 10-15% following application of BA at 50 or 100 mgL^{-1}. If the 4 days of 80% shade was administered immediately following thinner application (carbaryl 1000 $mg.L^{-1}$ or NAA 7 $mg.L^{-1}$), trees was nearly defruited. Administering a shading treatment for 4 days prior to thinner application had no influence on altering the thinner response to fruitlets.

Quinlan and Preston (1971) described how the competition among fruitlets and shoots for photosynthates limited the fruitlet set after June drop. Dennis (1986) reported that king fruitlets abscised less due to their major position in the cluster. Black *et al.* (2000) noted that the application of NAA or BA reduced the number of spurs bearing multiple fruits. Fruitlets in competition in the cluster, king fruitlets in competition with laterals and laterals in competition with kings and other laterals, abscised more than comparable fruitlets without competition in the cluster (Stopar, 1998). Lateral fruitlets were more subjected to abscission compared to king fruitlets and started to abscise at least 3-days earlier than king fruitlets (Kolarič *et al*., 2016).

A photosynthesis inhibitor metamitron has been recently reported to provoke fruitlet thinning effect if applied in very small amount comparing to its application as herbicide. Successful apple and pear fruitlet thinning with the use of metamitron was observed from many trials (Dorigoni and Lezzer, 2007; Clever 2007; McArtney and Obermiller, 2012) and was reported from many research station working in the frame of EUFRIN Working Group for Fruit Thinning (Costa, personal communications). Because of the suitable fruitlet thinning effect the manufacturing company was quite active in the past few years and prepared metamitron (with commercial name Brevis) for thinning agent purpose and went into registration for Europe and some other countries. Green and Costa (2013) summarized thinning properties of metamitron:

- The effect are concentration dependent,
- The application window is from 8 to 14 mm king fruit diameter for maximum response, but some thinning activity can be achieved up to 20 mm,
- The chemical was shown to be active in most of the cultivar tested so far,
- The phytotoxicity, although present, is temporary and it does not appear to adversely affect fruit finish, fruit quality, and productivity or return bloom.

Mostly two applications of metamitron are sprayed, first at 6-8 mm and secondly at 12-14 mm of king fruit diameter, and the final fruit set is mostly the sum of both applications. Internal fruit quality increased according to the reduction of crop load (Lafer, 2010). Adaptation the dosage to predicted light intensity at the time of application and/or a few days later seems crucial for thinning response of metamitron.

Conclusion

When thinning agents were applied prior to the ’June drop’ period they accelerated natural process of fruitlet abscission. Fruitlet drop are not accompanied by leaf abscission, nor do thinning agents induce leaf abscission when applied at this time. Processes of leaf abscission are much better explained than fruitlet abscission. Research is needed to provide a better understanding of the mechanism of action of chemical fruitlet thinners. The role of ethylene evolution following some chemical thinner applications is mostly considered as the final step of fruitlet abscission process, and not as the initial trigger. More support is given to the basic role of auxins and/or translocation of auxins when fruitlets in the cluster compete for setting in the so called “correlatively triggered” abscission process. Fruitlets with higher auxin transport sets better. At the same time more competition for carbohydrates in the fruitlet cluster provoked strong assimilation shortage and this may be the reason of weak fruitlet set. The connection between hormonal and/or assimilation reasons for apple fruitlet is not well explained yet. The effects of chemicals in inhibiting photosynthesis possibly in conjunction with shading experiments should be investigated more systematically to determine how important this effect is in inducing abscission.

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Invited lecture

BIOREGULATORS APPLICATION IN PEAR PRODUCTION

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Abstract. This short review report the results obtained with the main plant growth regulators/plant bioregulators (PGRs or PBRs) that are currently tested or used as registered pre-harvest and post-harvest compounds. The PBRs used in pre-harvest concern the regulation of fruit setting, bearing, fruit thinning and of shoot growth control. The auxin-like compounds are mainly used for fruit set and for pre-harvest drop control; Gibberellins for fruit set; auxins and citokinins for fruit thinning/quality improvement and prohexadione-Ca (Regalis) for shoot growth and fire-blight control. The PBRs for improving fruit quality and storability can be used in pre- and post-harvest. Aminoethoxyvinylglycine (AVG) is used in pre-harvest while 1- methylcyclopropene (1-MCP) can be used in cold storage room or, in some countries, also in pre-harvest (Harvista) to affect fruit post-harvest maturation and storability management.

Keywords: Auxin-like, GAs, CK, Prohexadione-Ca, AVG, 1-MCP, fruit set, *Pyrus communis*.

Introduction

This review aims to consider the growth regulators (PGRs or PBRs) used currently in the standard cultural management in commercial pear production or under experimental test in the main pear growing areas. PGRs or PBRs refers to natural and synthetic compounds that are used to control vegetative and reproductive tree growth and development. Many of the growth regulators are hormone-like substances that promote, inhibit or affect biological processes in plants. The PBRs must be used considering their efficiency for specific objective as well as their potential environmental impact to improve their performance, preserving human health and productive areas. The PBRs use must be integrated when the appropriate genetic and agronomic choices have been done to contribute increasing or maintaining the sustainability of the considered fruit-tree system. It has to be considered that PBRs are normally enhancing the natural response of the plant. As a consequence, when inappropriate agronomic or genetic choices have been done, it can be risky to rely on the use of PBRs to solve the problems. PBRs normally are active at physiological concentrations and undesirable side effects have always to be taken into consideration, especially when high rate are used.

PBRs function and mimic the activity governed by naturally occurring plant hormones that are generally molecules that exist at low concentration facilitating intercellular communications (Cleland, 1999).

Plant hormones are normally grouped into 5 categories: auxins, gibberellins, cytokinins, abscisic acid and ethylene. Other molecules, classified as growth substances, currently thought to have plant hormones characteristics, include oligosaccharides, jasmonates, salicylic acid, polyamines and brassinosteroids.
Endogenous plant hormones influence different developmental processes in a positive or negative manner but in order to reliably affect some physiological aspects of plants a better understanding of the mechanism of action of the PBRs is still to be further studied. Growth and reproductive potential of the tree can be manipulated using different compounds.

PBRs have the peculiarity that in some cases the same active ingredient can induce different responses (i.e. flower & fruit abscission; flowering) depending on the application time and rate used. In fact, their efficacy is influenced by internal and external factors (cultivar, tree vigor and fruit load, climatic conditions, cultural management, etc.). A holistic approach to understand and comprehend the results obtained with the use of growth regulators should be made considering the cultural management adopted (i.e. nutrition, pruning, training systems, etc.), the physiological status of the plant, the history of the orchard (alternate bearing), and weather conditions during the period of the PBRs application. In this way, models should be developed to forecast and help explaining tree responses.

In pear, the main registered pre-harvest and post-harvest PBRs are auxin-like compounds for fruit set and for pre-harvest drop control; Gibberellins for fruit set; auxins and citokinins for fruit thinning; prohexadione-Ca (Regalis) for shoot growth and fire-blight control; aminoethoxyvinylglycine (AVG), 1-Methylcyclopropene (1-MCP) for pre- and post harvest maturation and storability management.

Fruit setting & fruiting

Fruit setting and fruiting performance both in terms of quantity and quality can be directly affected by Auxin-like, GAs and CK or by the use of anti-gibberellin formulates, that controlling shoot growth, can divert the assimilates versus the fruiting (Fig.1).

Auxin-like substances

Indoleacetic acid (IAA) was found in plants, although auxin-like compounds used in agriculture (PBRs) include synthesized auxin-type hormone as 1-naphthaleneacetic acid (NAA), and its amide (NAAm) that have structural similarities with IAA, but are not found in plants.

Quite interesting to underline that auxin have the peculiarity, when applied at different phenological stages, to lead to effect completely different: in fact the use of auxin-like formulates during blooming increase fruit set, while when applied at fruitlet stage can induce fruit thinning or before harvest time can reduce the pre-harvest fruit abscission. In fact, NAA applied before expected harvest at the concentration from 100 to 200 g/ha might control pre-harvest drop. A possible explanation of this phenomenon might be related to the fact that fruit abscission is directly related to the expression of genes activating enzymes (i.e., cellulose and polygalacturonase) linked to an increase in ethylene associated with cell wall degradation in the abscission zone. The cell wall degradation enzymes are triggered by auxin reduction to a certain threshold that is normally associated to an ethylene synthesis increase. As a consequence, the auxin/ethylene relationship might control fruit abscission.

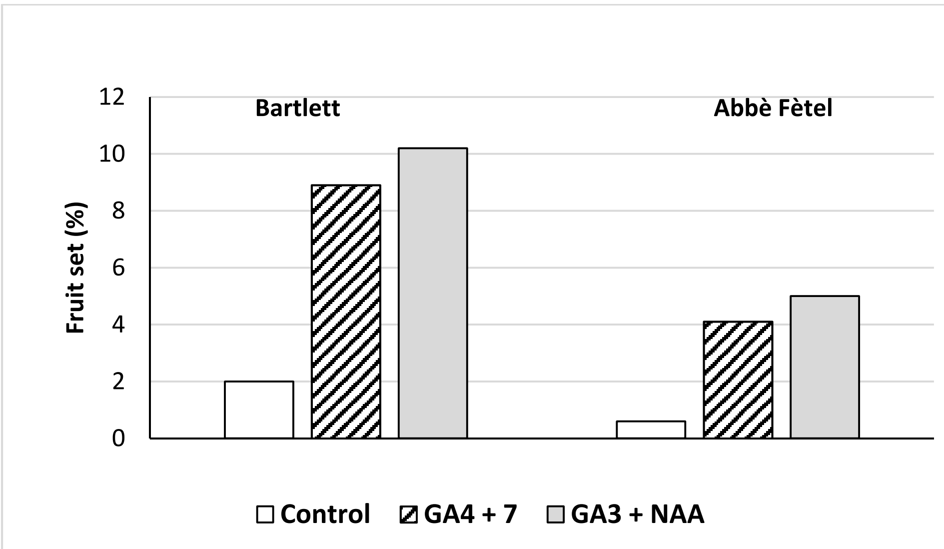

Figure1. Fruit set as affected by GAs and NAA in two pear cultivars (adapted from Sansavini *et al.*, 1981)

GAs and CK

Numerous gibberellins (GAs) are found in plants. GAs are a large group (more than 100) that have some biological activities and share the gibbane ring structure. GAs (both GA3 and GA 4+7 formulates) are used as a setting agent on some cultivar in particular and in situation where fruit set is presumed to be low when spring frost might have compromise fruit set.

Several researches were carried out since the ’60-’70 pointing out the possibility to increase fruit set with the GAs use (Luckwill, 1960; Varga, 1969; Gil *et al*., 1972; Wertheim, 1985; Dussi 2011).

GA4+7 is used alone or in combination with Citokinin (CK). Natural CK are a series of adenine molecules modified by the addition of 5-carbon side chains off the 6th position. Two CK groups include the zeatin-related and adenine-related molecules. CK-like include kinetin and 6-BA. The combination of GA and 6-BA is found in several commercial chemical (Promalin, Progerbalin LG®, Perlan®) belonging to different chemical companies.

The research trials performed on the use of these PBRs started in the ’60 and the ’70, but these PBRs are still used nowadays to increase fruit set and control fruiting.

The applications of auxin during the blooming period at concentration variable as related to the used compound have been able to increase up to 2-3 folds the fruit set percentage as compared to control (Sansavini *et al*., 1981; Nicotra, 1982).

Similar results were obtained with the use of GA3 at 20-30ppm applied at full bloom (fruit set 3 folds higher than untreated control). The effect was pronounced in the varieties that produce parthenocarpic fruits (Conference). It has to be considered that although parthenocarpic fruits might allow achieving an important yield, undesirable side effects as misshapen fruits might occur (Herrero, 1989; Vercammen *et al.,* 2015).

The application of the GA4+7 and 6-BA was initially used for enhancing the length of the fruits in apple but is become an important formulate adopted for fruit russeting control of apple and pear (Looney *et al.,* 2012). Research results indicated that the 6-benziladenine (6-BA) was inducing higher fruit size than control (Deckers and Schoofs, 2002; Stern, 2008; Brighenti *et al.,* 2010).

Some practical examples of the practical use of PBRs to enhance fruit set still refer to Auxins, GAs and CK:

- Auxin (i.e. commercial formulate AF96, a.i. 3,6% di NAA + 0,4% NAA) on William, Comice and Conference is applied at 20% open flower in a single application at a concentration ranging from 800 to 1200 ml/ha.
- AF96 is applied on Abbé Fètel at the same concentration but in two split applications; the 1st at 10-20% Open flower and the 2nd at 50% open flowers.
- Another application on Abbé Fètel concern the combination of AF96 at the concentration of 1000 ml/ha at “white finger bud” stage followed by two applications of GA4+7 and 6-BA (Promalin, Novagib or similar compounds), the 1st at 20% open flower and the 2nd after 4-5 days at a concentration of 250 ml/ha each application.

  As far as GAs alone, the standard application concern the use of GA3 or GA4+7:
- GA3 (several commercial compounds are available, i.e. Berelex at 10%, Falgro or 40%; Gibrelin at 2% or 20% a.i., etc) can be used at a concentration of 1000ml/ha in a single application or in two split application during bloom.
- GA 4+7 (several commercial compounds are available as Regulex10 SG, Gerlagib at 1% a.i., etc) can be applied in a single application at 30-40%

open flower at concentration of 800-1000 ml/ha or in two applications at 30% open flower and 4 days after at a concentration of 400-500 l/ha.

Both auxin-like, GAs and 6-BA have shown to be effective in controlling fruit set in several pear cultivars although there are positive and negative side-effect that have to be carefully considered. For instance it has to be considered that when GAs are used there is a potential risk to negatively affect the return bloom, especially when repeated application are performed to overcome the risk of poor setting compromised by spring frost. When the combination of GA4+7 and 6-BA are applied, the concentration had to be carefully considered since important concentration of 6-BA applied at fruitlet stage could induce fruit abscission.

Fruit thinning

Fruit thinning in pear represent an issue only for some cultivars. In fact, in some years, Bartlett and Conference might produce a high number of fruit that do not reach a marketable fruit at harvest. Conference is per sure the more demanding, but other cultivar might take advantages from the fruit thinning operation. Alternative to the hand thinning have been tested, normally transferring the information and the chemical tested on apple on pears (Williams and Edgerton, 1981; Stan *et al*., 1984; Wertheim, 2000).

In fact, NAA and NAAm have proved to reduce fruit set when applied at 15 to 20ppm approximately 15 to 20 days after full bloom (Williams and Edgerton, 1981, Wertheim, 2000).

Auxin and 6-BA are the PBRs normally used for pear fruit thinning (Giménez *et al*., 2010). A tank mix application of 6-benzyladenine (6-BA) and 1-naphtalene acetic acid (NAA) showed to be, in some situation, very effective in inducing fruit abscission. However concentrations and time of application are essential in obtaining the desired results. Application of NAA and 6-BA induce over-thinning in ‘Conference’ pears when the application was performed at 8 mm fruit diameter, while later applications (15 mm fruit diameter) lead to better results (Maas *et al*., 2010; Fernandes, 2015). Similar effects were obtained in Spain on Conference and Blanquilla cultivar, when a 6-BA + NAA combination was tested (Asin *et al*., 2010). Fruit quality can also be improved by the fruit thinning technique: Canli and Pektas (2015) reported positive effect on fruit quality (expressed as fruit size, weight, diameter and length) when a tank-mix of 6-BA + GA (at 25 and 50 ppm) and of 6-BA at 100ppm were applied. In addition pear fruits reached a higher soluble solids content than the untreated. Results concerning a fruit size enhancement induced by with 6-BA applications were also reported on ‘Williams’ pear (Dussi and Sugar, 2011) and on Conference pear (Basak *et al*., 2016) (Fig. 2).

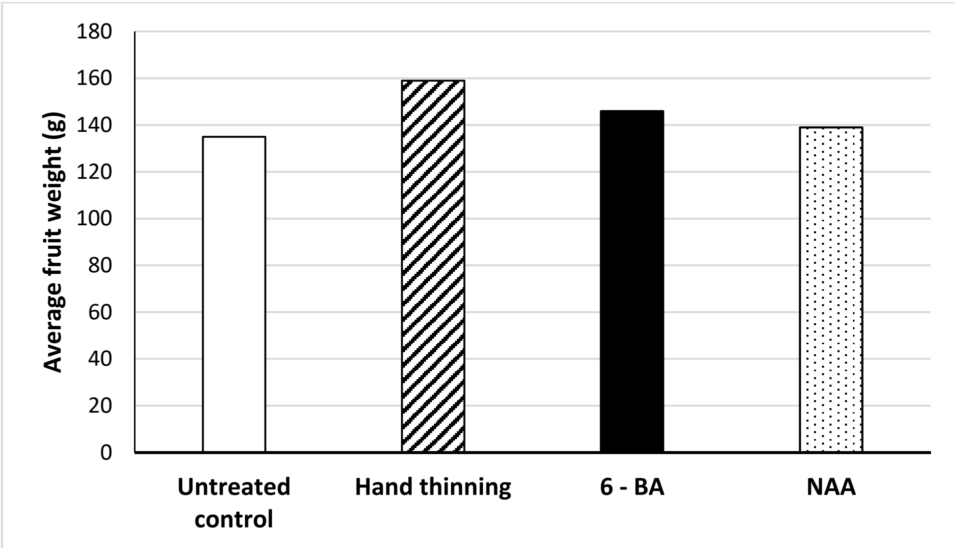

Figure 2. Average fruit weight reached in cv Conference 6-BA and NAA treated trees as compared to control (Source: adapted from Basak et al., 2016).

Other compounds are used on pear for inducing fruit thinning: Ammonium thiosulphate (ATS) showed an efficacy although bloom application increased some undesirable fruit russeting.

More recent interesting fruit thinning results on pear have also been obtained with Metamitrom (commercial name Brevis) (Maas and van der Steeg, 2011) while other experimental PBRs, like abscisic acid (ABA) and 1-aminocyclopropene-1-carboxylic acid (ACC), are also under testing for evaluating their potential thinning efficacy.

In the practice, common strategy are based on the use of NAAm (suggested for Bartlett and Conference at 10 to 50 ppm at petal fall or within 5 to 7 days after petal fall) or NAA (Dirager 3,3% a.i. or Obsthormon 24A at 7,5% a.i.) on Conference and Bartlett at 9mm fruit diameter.

Vegetative growth control

The vegetative control is essential in pear orchard management to select the best wood for the next year production, for return bloom and in general for reducing the competition of the vegetative sinks versus the reproductive ones. The standard method is summer pruning performed by hand. The hand operation is costly and time demanding and alternative chemical and mechanical methods have been tested. The chemical method is based on the use of growth retardants. Several growth retardant have been available until mid-‘80, like Alar, Cicocel, PP333 (Pfammattar, 1977; Modlibowska, and Wickenden, 1977; Nicotra, 1982). Most of these chemicals have been banned (Alar) or retired (CCC) from the market on pear. PP333 (a.i. paclobutrazol; commercial name Cultar) has not been used in Italy until two years ago, when the authorization procedure for introducing Paclobutrazol was requested and completed and now the growth retardant is available on pear orchard (Fig.3).

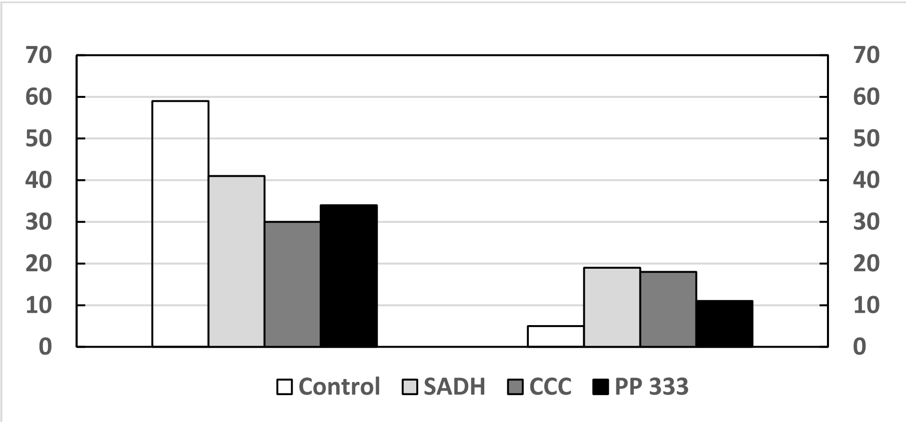

Figure 3. Shoot growth and yield/tree as affected by different growth retardants in AbbèFetel.

Prohexadione-Ca, instead is one of the newest and most interesting growth retardant authorized for apple and pear. It is a shoot growth retardant that may result in different responses depending on the pear cultivar and rate used. An important research activity was carried out with Prohexadione-Ca on pear few years ago (Costa *et al*., 2004; Rademacher, 2004).

The interest on the use of prohexadione-Ca depended upon the need to control vegetative growth in a new high density planted orchard, by the lack of growth retardant available (Alar and CCC) and by the fire blight suppression induced by Prohexadione-Ca. Prohexadione-Ca was selected because represented at that time a new generation of growth retardants characterized by low toxicity. In addition, the mechanism of action was deeply investigated showing its involvement in GAs biosynthesis and its interesting effects against some pomefruit diseases while no major negative side effect were reported (Costa *et al*., 2004; Rademacher, 2004).

The study on the mode of action pointed out that Prohexadione-Ca may interfere with dioxygenase catalyzing different specific 2-oxoglutarate dependent reactions, such GA20 oxidase and related enzyme that determine the reduction of shoot growth and with the flavanone 3-hydroxylase which determine an induction of resistance against pathogen infection. Prohexadione-Ca interferes also with the ascorbate-dependent ACC oxidase that determines a delayed senescence and reduced fruit.

The experiments carried out to evaluate the effect on vegetative and cropping performance and on fire blight suppression pointed out that the growth retardant effect of Regalis is related to the cultivar, to the vigor of the considered combination and to the concentration used (Costa *et al*., 2004; Rademacher *et al*., 2004; Deckers *et al*., 2005; Maas, 2005) (Fig.4).

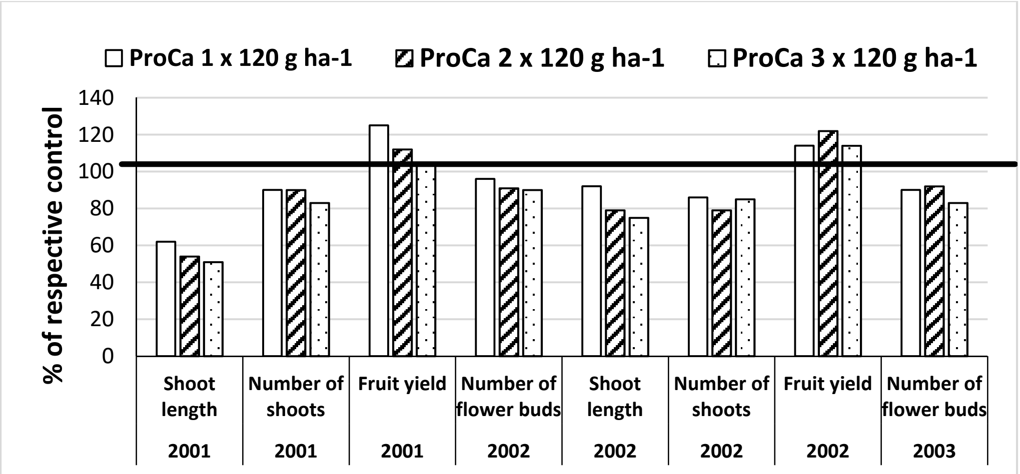

Figure 4. Effect of repeated application of Pro-Ca (1st application at the 3rd to 5th expanded leaf followed by 3 to 5 weeks sprays) on vegetative and reproductive parameters of cv Conference/Quince C tree (Source: Rademacher *et al*., 2004).

As far as the fire blight control, the application of Regalis showed an interesting activity and its effect was magnified, in some experimental conditions, when the Regalis was applied in combination with P10C (*Pantoea agglomerans)* (Vanneste *et al*., 2002; Costa *et al*., 2006; Vanneste, 2011) (Fig.5).

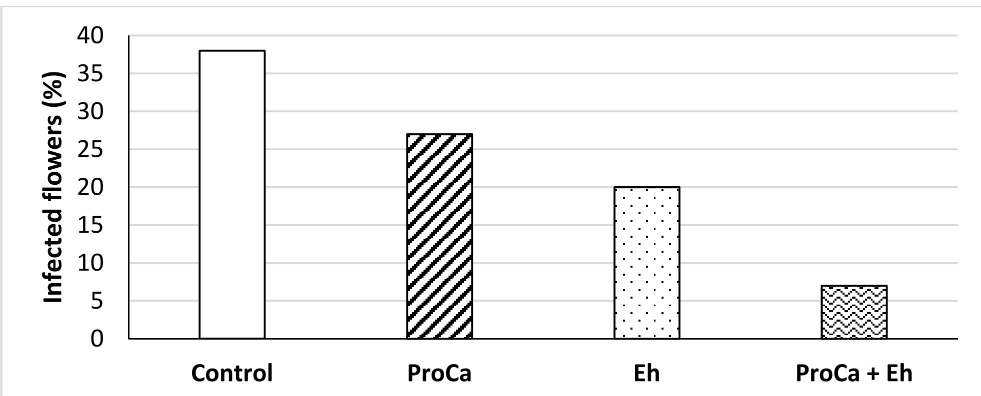

Figure 5. Effect of Pro-Ca and P10C (*Erwinia herbicola*) on Gala apple flower. (Source: Costa *et al*., 2002).

The negative effects that were detected, in some circumstances, on the return bloom represent the main concerns on the use of Regalis. The Regalis determine a reduction of the return bloom and this effect might depend upon the cultivar and the vigor of the considered combination.

Other PBRs like auxins and Ethephon, that might offer a certain growth control, are more effective in positively affect return bloom. NAA and/or Ethephon can be applied at 500-700 ml/ha in one or two application to control the vegetation and affect return bloom. NAA in a “paste” form can be also applied on the surface of important pruning cut to control apical dominance.

Fruit maturation, ripening and shelf-life management

Ethylene is considered the hormone that control the fruit ripening syndrome and PBRs able to control ethylene allow to control the fruit ripening in various pear cultivars.

In the recent years, several formulate able to interfere with ethylene biosynthesis or ethylene perception, have been found. Aminoethoxyvinilglicine (AVG; a.i. inReTain®) and 1-Methyl cyclopropene (1-MCP; a.i. in Smart FreshTM) are respectively inhibitors of enzyme important for ethylene biosynthesis or control the ethylene perception.

AVG initially experimentally tested to increase fruit set (Lombard and Richardson, 1982) find a commercial application in pre-harvest to control ripening. In fact, ReTain® can be used to extend the normal harvest period; it can be applied up to 4 weeks prior to harvest at 100-200 g/ha active ingredients in 1000 liters of spray volume to improve the fruit firmness and extends harvest period. ReTain® is also effective in reducing the pre-harvest abscission from 7 to 14 day as compared to untreated trees. As a result of extending the harvest period, fruit size may be increased. Pre-harvest applications of ReTain® also increased storability of pears and reduce senescence and storage disorders. The effectiveness is dependent upon application time, concentration and fruit ripening uniformity at the moment of application (Clayton *et al*., 2000; Dussi *et al*., 2002; Andreotti *et al*., 2004).

Smart FreshTM (a.i. 1 MCP) is instead a PBR that is applied in a gaseous form in post-harvest in Europe while in USA a pre-harvest formulate is also been tested (HarvistaTM 1.3 SC). The molecule has a higher affinity than ethylene for the ethylene receptor and is able to reduce the ethylene autocatalytic reaction determining a reduction of the ethylene amount available. Smart FreshTM showed to be very active in controlling ethylene production and fruit ripening (Tab. 1) (Ziosi *et al*., 2008).

Table 1. Influence of ripening stage and 1-MCP on ethylene production and fruit ripening. 'Abbé Fétél' pears were divided in in the classes 1 and 2 of homogeneous ripening (expressed as I_{AD}); 1-MCP was applied at 0.3 □l l^{-1} for 24 h (Source: Ziosi *et al.,* 2008).

	Ethylene (nl h^{-1} g^{-1} FW)				IAD		
Ripening stage	Months				Months		
	0	3	5	7	3	5	7
Class 1 (I_{AD} 2.3-2.0)	**C**	16.5	38.5	36.3	1.6	1.0	1.0
	T	9.1	24.4	33.6	1.8	1.5	1.5
Class 2 (I_{AD} 2.0-1.7)	**C**	22.6	19.2	34.2	1.1	0.7	0.6
	T	8.4	10.7	42.2	1.5	1.3	0.9

However, Smart Fresh^{TM}, from one side indicated the capability to slow down the fruit softening rate and a reduction of fruit losses during storage, although underlined some concerns about the capability to recover the ripening capacity of the treated pear fruit after cold storage (Rizzolo *et al*., 2014). In fact, in some trials, 1-MCP treated fruits did not reach the typical skin color and the firmness was maintained at very high level (Vidoni *et al*., 2013; 2015; Wang *et al*., 2015). In addition fruits harvested at different ripening stage showed that during storage the fruit-ripening trend is different between the two fruit ripening classes and the reached values remain always lower for 1-MCP treated fruits (Fig.7). Some researchers tested the possibility to prevent ripening blockage in 1-MCP treated 'Abbé Fetel' pears by temperature management (Cucchi and Regiroli, 2011; Folchi *et al*., 2014; Wang *et al.* 2015).

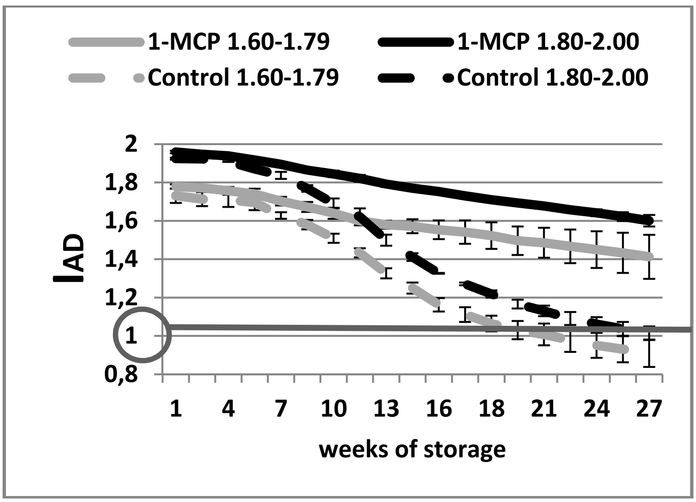

Figure 7. Differences between fruits harvested at a different ripening stage (expressed as Index of Absorbance difference (IAD) determined with the DA-Meter). Values for the riper fruits ranged from IAD **1.6 to 1.79** and for the less ripe from IAD **1.80 to 2.00.** Control and 1-MCP treated fruits maintain during the storage period the ripening value differences they had at harvest and fruits 1-MCP treated have a completely different trend as compared to the control fruits harvested at the same ripening stage.

Nowadays, NAA, AVG, and 1-MCP (HarvistaTM 1.3 SC) are efficient tools for controlling pre-harvest fruit drop, extending harvest window, and increasing storability in pears. Application timing, rate, and fruit harvest maturity are critical for efficacy and reducing the possible negative effects of the PBRs on pears.

It has to be pointed out that also auxins might play an important role in the maturation and ripening process of pear fruit as well as the growth substances polyamines that have been tested successfully in other fruit species (Bregoli *et al*., 2005; 2006). There is a close relationship between auxin, polyamines and ethylene. In pear, for example, NAA has been thought to stimulate the production of ethylene and can hasten fruit maturation and softening. It is known in the practice that the use of auxin-like formulates, such as AF96 induced positive effect on the post-harvest management.

Final remarks

Plant bioregulators (PBRs) that mimic and function as the naturally occurring plant hormones affecting vegetative and fruiting parameters, improving yield, quality and postharvest life and representing an important tool in fruit tree management.

In pear, the use of PBRs started several years ago and nowadays is still an important and necessary cultural management operation. Auxin-like formulates were found useful in increasing fruit set, overcoming biennial bearing and counteracting pre-harvest drop. Gibberellins and cytokinins also increased fruit yield and ameliorate shape and quality of fruit. Other areas of fruit production where PBRs are especially useful include prevention of pre-harvest fruit drop, control of vegetative growth, enhancement of flower bud formation and control of fruit ripening.

In fact, in recent years, the introduction of the Prohexadione-calcium, an inhibitor of gibberellin biosynthesis, allow to control shoot growth and altering plant metabolism to impart resistance to insects and diseases. More recently, other compounds as aminoethoxyvinylglycine, an ethylene biosynthesis inhibitor and 1-methylcyclopropene (1-MCP), a competitive inhibitor of ethylene, allow extending harvest window, postharvest life improving storage quality of fruit.

The research on the use of PBRs in pear is still ongoing. Among the newly proposed PBRs, the naturally occurring hormone, Abscisic acid can potentially overcome plant stress, enhancing fruit color, and early fruit drop, but its effectiveness in pears needs to be confirmed with further research.

However, it has to be considered that the use of PBRs is a difficult technique. In fact, plant bioregulators have the peculiarity that, in some circumstances, the same active ingredient can induce different responses depending on the application time and rate used. It has to be carefully considered that the PBRs effectiveness is affected by several internal and external factors like cultivar, tree vigor and yield, climatic conditions during the application period as well as the application methodology used. Of course this complicates the scenario and PBRs must be used in a proper way to obtain the desired results.

As a conclusive remark, the plant growth or bioregulators (PGRs or PBRs) in pear are an important tool, although, they must be considered a part of a larger portfolio of options to be integrated into a whole sustainable, systematic approach program for controlling vigor and improving cropping. In anycase a proper use of the PBRs require a deep understanding of the physiological mechanism of the process to control and the nature of the active ingredient of the used principle to obtain the main desired effect and avoid the collateral negative side-effects.

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Invited lecture

REGULATION OF FRUITING IN PLUM PRODUCTION

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Abstract. This short overview article describes different strategies to adjust crop loads in plums in order to get regular cropping, improve fruit size and fruit quality. There are three principal methods of regulating the crop loads of plum, which can be combined: numbers of flowers on the tree can be reduced, flowers can be prevented from fruit setting and the amount of fruitlets can be reduced by thinning methods. The methods of achieving these strategies, by manual, mechanical and chemical means are described and discussed.

Keywords: ACC, ATS, ethephon, fruit quality, GAs, mechanical thinning, *Prunus domestica*, *Prunus salicina*, sulfur, thinning, yield.

Introduction

Most European and Japanese plum cultivars produce few flowers and even fewer fruits in the two or three years following planting of young trees. Thereafter they frequently initiate and form too many flowers and set too many fruits to obtain regular and marketable crops from year to year. If consistent cropping is to be sustained and fruit quality maximized, the fruit set remained by the tree must be balanced with the tree size and the leaf area (Måge, 1994, Webster and Spencer, 2000). In addition, adjustment of the crop load will protect branches from breakage due to the heavy weights of the fruits.

The abundance of flowers produced is often far in excess of the grower's target for fruit set and to retain an optimum number of marketable fruits. For example a fruit set of only 5% flowers on the plum cultivar Victoria are required to provide a full crop (Webster and Holland, 1993) and for apple a fruit set of 10% flowers is sufficient (Meland, 1998). At this crop load level, most of the fruits will be in the sizes preferred by the fresh fruit market (Byers, 1997).

When too many fruits are set, other problems in addition to fruit size and quality, like branch breakage can occur. Excessive fruit numbers often reduce the numbers and quality of flowers in the following season and may lead to the establishment of a biennial pattern of cropping. Pollination, pollen-tube growth and especially fertilization and seed growth lead to a burst in hormone activity in the ovary (Luckwill, 1953). Large seed numbers of the fruits within the tree produce gibberellins (Chan and Cain, 1967; Hoad, 1984). These gibberellins move from fruits into the adjacent spurs and leaf axils where they inhibit the initiation or stimulation of the abscission of new floral primordial. Other hormones like auxin likely may play a role in biennial bearing and the effect of crop load on floral initiation has yet to be fully explained (Bangerth, 1977).

The crop load effect is little investigated in plums. The optimum goal is to produce maximum and annual crop of high fruit quality under the climatic conditions for a region. The crop levels have an impact on the growth of the tree. Leaf and whole canopy photosynthesis increased curvilinear with higher crop in apples (Palmer, 1992). The reduction in photosynthesis in trees with lower fruit number frequently occurs after shoots have terminated vegetative growth. Increasing fruit load in apples led to increases in dry matter production, per unit leaf area and partitioning to fruit and to decreases in fruit size (Palmer, 1992). Leaf photosynthesis was increased in cropping trees in July and August at the time of maximum fruit load. Similar approaches are expected to take place in plums, but have so far not been investigated.

Fruits compete with each other for water, nutrients, assimilate, and with other vegetative sinks in the tree such as vegetative shoots and roots. The leaf areas of the trees, the amount of available light (light interception) and the ambient temperature are important for the total carbon production and influence the optimal crop load (Palmer, 1992). Management factors like the choice of rootstocks used, the tree spacing and the tree pruning and management are factors which have a strong impact on the crop loads as well. The within tree competition can be altered by other management techniques like manipulation of the vegetative growth (shoot pruning/ training) and root growth (root pruning/restriction).

Optimum crop levels are expressed as number of fruits per 100 flowers, number per unit branch length or numbers per trunk cross sectional area and differ for each cultivar and change for the same cultivar when grown on different sites. It is difficult to estimate and establish general guidelines for optimal crop loads for different plum cultivars. They have to be defined for each species/cultivar in the different climatic environments.

Strategies for optimizing crop load

Regulation of crop load is a prerequisite to obtain the optimum fruit load and yield of marketable fruit size and fruit quality. In years with few flowers fruit set needs to be promoted, but in most years flowering is abundant and fruit set needs to be limited to avoid oversetting and too high yields of poor quality fruits (Fig. 1). Thinning can be done at various times; pre-bloom, at full bloom and post-bloom. Pruning is as well one method of thinning (Njoroge and Reighard, 2008). However, even when stone fruit trees are properly pruned, they still often set too many fruit (DeJong and Grossman, 1994). The severity of thinning, as well as the timing, is closely linked to the reproductive and vegetative performance of the tree (Costa and Vizzotto, 2000). Thinning must therefore be done annually, to achieve the advantages it has on flower number, fruit size, fruit quality, fruit-to-shoot ratio and in preventing alternate bearing (Costa et al., 1983).

There are three principal methods of regulating the crop loads of plum. Numbers of flowers on the tree can be reduced; flowers can be prevented from fruit setting and the amount of fruitlets reduced by thinning methods (Dennis, 2000). One or more of these methods can be combined.

Figure 1. Oversetting of ‘Opal’ plums (left) and ‘Jubileum ‘(right). (Photo’s: Mekjell Meland).

Reduction of flowering intensity

It is difficult to control the numbers and quality of the flowers developed and distributed around in the tree and their fruit set. The reduction can be conducted by management techniques like pruning prior to flowering. It is important to leave branches with sufficient fruit bearing capacity and at the same time stimulate to renewed extension growth for floral buds and fruiting for coming years.

Hormones like gibberellins used in one season can depress flowering the next spring (Gonzáles-Rossia et al., 2006; Southwick and Glozer, 2010). One of the chemical thinning approaches for plums is to use gibberellins, e.g. gibberellic acid (GA_3), but results are often inconsistent. GA3 applied during flower induction will reduce flowering the next season and indirectly reduce the number of fruits, which will lead to a reduction in hand thinning costs (Gonzáles-Rossia et al., 2006). Therefore, to be effective, GA_3 must be applied when flowerbuds differentiation can be affected (Costa and Vizzotto, 2000). The main reason why GA_3 sprays are not used as a chemical thinner is because “thinning” is performed long before bloom and climatic conditions, i.e. frost during bloom, might still negatively influence fruit set of the fewer blossoms (Costa and Vizzotto, 2000).

The effects of Gibberellic Acid (GA_3) on regulating crop load of several *Prunus* species are well known (Byers et al., 2003; Conveva and Cline, 2006).

However, for the most of these studies, timing of application coincided with pit hardening (Stage III of fruit growth) and, which mostly improves fruit firmness and delays fruit maturity in the year of application. In a recent study on sweet cherries, Lenahan et al. (2006) found that GA_3 applied at the end of Stage I of fruit growth in an “off-year”, resulted in floral bud inhibition that year, and reduced return bloom and yield the following year while improving fruit quality.

Gibberellic acid (GA_3) was tested as a novel approach to regulate the crop load of the plum cultivar ‘Opal’ at Ullensvang, western Norway (Meland and Kaiser, 2014). The objective was to reduce flower bud induction in the “off-year” thus adjusting crop load the subsequent year. In 2008, an “off-year”, GA_3 was applied to 9 year-old ‘Opal’ trees as a high volume spray to the point of run-off at 50 ppm or 100 ppm at either 5 weeks after full bloom or 10 weeks after full bloom or on both dates and compared with untreated control trees. Trees were unthinned the first year but then thinned to commercial standard the following year. In the year of application, total yield was recorded and fruit quality evaluated. Return bloom, fruit set, yield and fruit quality were assessed the subsequent year. In general, there were no significant differences in crop load of all treated trees compared to untreated trees in the year of application (non-target crop).

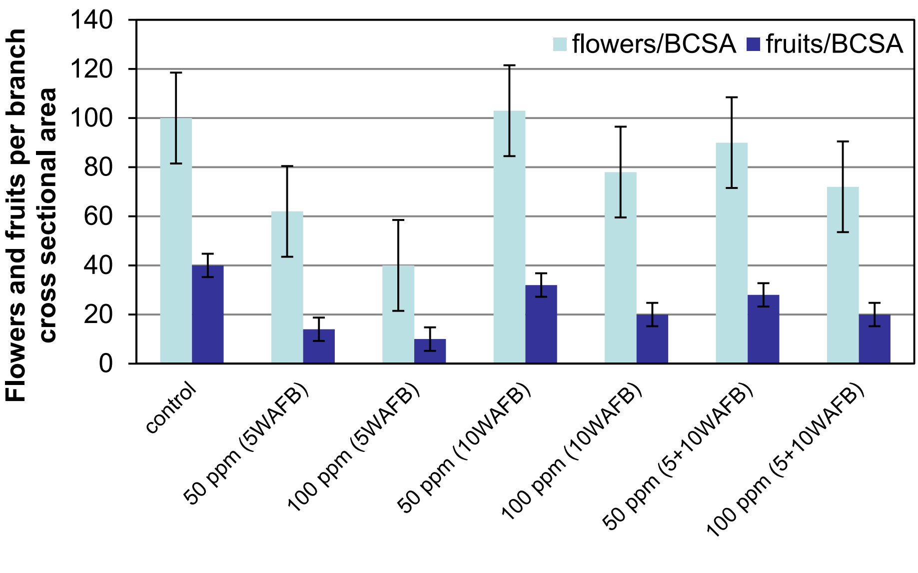

Figure 2. Effects of GA_3 applications to ‘Opal’ plum trees 5 and 10 weeks after full bloom in 2008 on return bloom and fruit set in 2009. (Source: Meland and Kaiser, 2014).

However, fruit weight increased slightly on those trees when GA_3 was applied 5 weeks after full bloom compared to all other treatments and untreated trees. The following year (target crop) fruit set was significantly reduced for all GA_3

treatments (Fig. 2). The most effective application time was 5 weeks after full bloom. Before thinning, initial fruit set was greatest on untreated trees as well as on those trees treated with GA_3 10 weeks after full bloom. Fruit weight and fruit color were significantly better on trees with the least fruit set. GA_3 applications had no effect on fruit firmness. It is concluded that GA_3 is an effective tool for inhibiting flower bud induction in an "off-year" thus enabling crop load management the subsequent "on-year".

Other fruitlets thinners inhibit the gibberellin biosynthesis or auxin transport, other thinners are inhibiting the photosynthesis. Reducing photosynthesis by shading trees is very effective in promoting fruitlet abscission (Byers et al., 1985; Stopar, 1998).

Flower thinning

The fruit size at harvest can be improved by reducing the competition between fruits for water and assimilates in the early stage of fruitlet development. Early reduction in the season by flower thinning, improves the amount of floral primordia the next year (Goffinet et al., 1995; Hansen, 1971; Meland, 1998). This is particular important for cultivars with abundant fruit set and for cultivars situated in areas with favourable conditions for fruit set. However, growers consider flower thinning as a high risk and like to be sure to have adequate fruit set before conducting any reduction of the crop load. Flower thinning can be conducted by hand, mechanically and by chemical methods.

Figure 3. The plums trees have abundant of flowers (left). Handthinning is labouring intensive (right). (Photo's: Mekjell Meland).

Hand and mechanical thinning of flowers

Flowers can be removed by mechanical means. Flowers number can be reduced by dormancy pruning, physical removal by hand (Fig. 3) or specialized brushes from machines. Cultivars with very high floral abundance usually require much hand labour and costs can be far too much to be economically achievable.

There are different mechanical thinning devices available on the market, both handheld and devices mounted on the front of a tractor. The use of a mechanical thinning device is independent of the production-scheme, being suitable for both integrated, as well as organic fruit cultivation. Mechanical thinning is best suitable for vertical, tall, slender spindle type trees and fruit-wall-trained trees, with mostly thinner, flexible branches, which provide access to the trunk without solid/thick vertical structural branches. Two main concepts are developed for mechanical blossom thinning of fruit trees. The ‘Baum’ was developed at the University of Bonn, Germany (Damerow et al., 2007). This thinning device comprises a 3 m tall, vertical square beam mast with three horizontal arms and variable angle rotors arranged vertically up the mast (Fig. 4). Each of the arms can be adjusted vertically from a height of 0.50 m to 2.30 above the ground allowing for adaptation to the type of fruit tree and for a vertical coverage of the tree canopy ranging from 0.25 m to 3.25 m. Radiating from four sides of each rotor at right angles are 0.35 m long, stiff plastic tines that act as whips when rotating and passing through the trees. The rotors are actuated by the tractor’s hydraulic system and optimum rotor speeds range from 320 to 420 rpm, while optimum tractor speeds range between 5 and 7.5 km/h. Increases in rotor speed and increases in tractor speed have opposing effects; while an increase in rotor speed enhances the thinning efficacy, increases in tractor speed reduces this effect .

The second machine is as well a rotating string thinner (Darwin 300; Fruit-Tec, Deggenhausertal, Germany) designed by H. Gessler, a German grower, to remove apple blossoms in organic orchards. A description of the string thinner and details of its application can be found in Bertschinger et al., (1998). The string thinner consisted of a tractor-mounted frame with a 3.0-m-tall vertical spindle in the center of the frame. Attached to the spindle there are 36 steel plates securing a total of 648 plastic cords each measuring 50 cm long. The speed of the clockwise rotating spindle is adjusted with a hydraulic motor. The height and angle of the frame is adjustable to conform to the vertical inclination of the tree canopy, and the intensity of thinning is adjustable by changing the number of strings and the rotation speed.

The third machine is a hand-held device developed in France with rotating plastic strings at the end of a stick that can be used to partially remove flowers and young fruitlets at specific areas within a tree (Martin et al.*,* 2010) (Fig. 5).

Mechanical thinning of the plum cultivar ‘Ortenauer’ using the three rotors device ‘Baum’ was successfully employed at 400-500 rpm at a tractor speed of 5 km/h and reduced hand thinning by 180 hours up to 310 hours per ha when used alone. A combination of mechanical thinning followed by ATS application further reduced labor by about 20 or more hours per ha (Weber, 2013). Mechanical thinning of peaches during bloom by the Darwin machine reduced the crop load by an average of 36%, decreased the follow up hand thinning time and increased fruit in higher market value size categories by 35%. It was concluded that the mechanical thinning appears to be a promising technique for supplementing hand thinning in apple and peach trees (Schupp et al., 2008).

Figure 4. The Baum machine (left) and the Darwin machine (right) both originating from Germany. (Photo’s: Frank Maas, left; Michael Blanke, right).

Figure 5. The Electroflor hand-held mechanical thinning device developed in France (Photo’s: Frank Maas).

Chemical thinning of flowers

Chemical methods of flower thinning have been used on *Prunus spp*. for many years (Grauslund, 1980; Jakob, 1998, Kvåle, 1978). The chemicals spayed at bloom in some way will prevent their pollination and/or fertilization (Byers et al., 2003). All these chemicals reduce the competition between fruits at an earlier stage in the season than is achieved using fruitlet thinners later. Blossom thinners used alone or in combination with fruitlet thinning will lead to increased fruit size and return bloom. For alternate bearing cultivars with small fruits, only fruitlets thinning are often not sufficient to achieve these goals.

Two approaches are available for blossom thinning. One method is to reduce the number of healthy flowers by spraying with caustic compounds that burn stigmas and styles and inhibit pollination. A second method involves chemicals that enhance ethylene formation of the flowers. During flowering the chances of stimulating ethylene-induced fruit drop is relatively high. By applying extra ethylene through spraying with etephon reduces the auxin level in the plant tissue and enhancing the flower abscission. Ethephon applied at anthesis increases the whole senescence and contribute to the increased abscission (Sanzol and Herrero, 2001).

Flower thinning compounds

The fertilizer ammonium thiosulphate (ATS) has been extensively tested as a flower thinner for many fruit crops in the last decades (Wertheim, 1998). ATS is thought to thin by the desiccation of flowers and damage to the base of the flower peduncle. Its efficacy is therefore influenced greatly by the proportions of flowers at vulnerable stages in relation to the time of spraying (Byers et al., 1985; Byers et al., 2003). In experiments conducted in 1998 and 1999 the final fruit set was reduced to about half of the unthinned trees when 1.5% ATS were applied at full bloom to the cultivar ‘Victoria’. The yields were significantly reduced and the pack out percentage increased (Meland, 2004). Webster and Holland (1993) reported that two or three sprays at intervals during the blossom period were much more effective than a single spray. Blossoms sprayed at or soon after anthesis were more sensitive to ATS than those sprayed earlier. The stigma is the most sensitive tissue part of the flower; disruption of pollination and fertilization appears to be the main effect of blossom thinning treatments. Multiple applications in these trials would likely have increased the thinning effect because of the low temperatures and extended flowering period in 1998 and 1999. Some minor leaf damage was recorded when treating the trees with ATS. These leaf symptoms disappeared during the season and seemed to have no effect on the growth of the trees

In apple the efficacy of inhibition of fruit set by ATS was shown to be very dependent on the concentration and timing of ATS application after flower bud opening (Maas, 2016). The time window for ATS to affect fruit set was shorter at higher temperatures and corresponded to the calculated pollen tube growth rate. At 50% growth of the pollen tube of the distance between the stigma and ovary of the flower, the efficacy of inhibition of fertilization and subsequent fruit set decreased by about 50%. At 80% pollen tube growth or more, ATS application no longer inhibited fruit set in ‘Elstar’apple (Maas, 2016). The time for the pollen tube to reach the ovary according to the pollen tube growth model used and the local temperature conditions during the trial varied between 95 and 49 hours at average daily temperatures of 13.5 and 21.2 °C, respectively. These results clearly indicate that the time window for an ATS thinning application is narrow and becomes even more narrow at higher temperature during bloom.

Table 1. The effects of different thinning agents on yield efficiency, total yield, fruit size, fruit quality and return bloom of ’Opal’ plums in 2000 (Source: Meland, 2007).

Treatment	Flower clusters per tree[1]	Yield kg per tree	Yield, % >36 mm fruit size	Fruit weight, g	Soluble solids, %	Return bloom[2]
Untreated	7.3	42.5	41	28	12.8	7.3
Handthinned	7.7	16.6	93	41	16.8	9.0
1,0% ATS	8.0	28.2	88	38	16.2	8.3
5% lime sulphur	7.0	20.9	92	41	16.7	8.3
LSD, P=0.05%	NS	11.6	22	5	2.0	NS

[1] Flower clusters scores 1-9 where 0= no flowering and 9= very abundant flowering
[2] Return bloom scores 1-9 where 0= no flowering and 9= very abundant flowering.

A single dilute application at full bloom of with 1% ATS or 5% lime sulphur at full bloom to the cultivar ‘Opal’ reduced fruit set and crop load and increased the fruit quality and return bloom (Meland, 2007) (Table 1).

Sulphur-containing chemicals are blossom thinners and have been mainly used in Northern Europe. Lime sulphur sprays up to 5% are most effectively applied at full bloom. (Kvåle and Ystaas 1969). However, sometimes these chemicals give inconsistent results on a commercial scale. Recently, limitations for the use of chemicals in the orchards have come forward. The traditionally used compound lime sulphur is withdrawn in some countries by manufacturers because of the cost of registration.

In Norway, trials were conducted on mature ‘Jubileum’/’St. Julien’ A’ trees treated with different concentrations of sulfur (0.4%, 0.8%, 2% and 4%); a mixture 0.4% sulphur plus 2% soya oil; and 2% soya oil plus 1.5% ammoniumthiosulphate, ATS (powder and liquid formulation) at full bloom and compared to untreated control and handthinned check in 2008. Treatments were applied to single whole tree plots in a randomized complete block design with six replications. Experimental trees were sprayed to the point of run-off with a hand sprayer and spraying dates were

May 6 (2008). Flower thinners were efficient at relatively low temperatures. In 2008 all thinning treatments reduced fruit set significantly compared to unthinned controls. Sulfur, soya oil both alone and in combination was less effective than ATS. Sulfur at different rates had a moderate thinning effect but it is not recommended for use in plum thinning under these conditions. Instead, 1.5% ATS application at full bloom resulted in adequate thinning of ‘Jubileum’ plums under cool mesic northern climatic conditions (Meland and Kaiser*,* 2012).

Reduction of amounts of fruitlets

Hand thinning of fruitlets

This method is widely practiced and is still the most reliable method of achieving optimum crop loads and fruit distribution. However, hand thinning is very laboured intensive and expensive. Guidelines for hand-thinning vary within the cultivars and the growing conditions. To space the fruits about 5- 7 cm apart on the branches is a rule of thumb. It has not been investigated which crop load potential is the optimum for different plum cultivars in order to produce maximum crop load and still achieve the fruit quality wanted.

The European plum cultivar ‘Opal’, widely grown in Scandinavia, frequently initiates too many flowers and set too many fruits. If excess fruitlets remain on the trees until harvest, the crop consists of small, unmarketable fruits of low fruit quality and return bloom will be reduced. For two seasons starting in 2008 on mature ‘Opal’/‘St. Julien A’ trees, two crop loads 50% and 25% flowers reduced were established at full bloom and at 10-12 mm fruitlet size and compared with an un-thinned control treatment (Table 2). Final fruit set varied from 63% on the control trees to 18% when thinned at bloom. Yield was negatively correlated with the fruit set response. Thinning at the fruitlet stage resulted in smaller fruits at the same crop level compared to flower thinning. Fruit quality parameters characterized by bright yellow skin background colour, red surface colour and the concentrations of soluble solids increased significantly as the crop load was reduced. Other fruit quality parameters like percentage acidity were not significantly different and did not show a clear response to the degree of thinning. Return bloom was promoted most when trees were thinned at bloom the year before.

Hand thinning 10-12 mm fruitlets to 25% fruit set resulted in the largest fruit on average (42 g/fruit) with acceptable yields (37 kg/tree) when compared to unthinned control trees (31 g/fruit and 54 kg/tree respectively). Flower-thinning to 25% of full bloom resulted in unacceptably low fruit set (18%) and the lowest yields (23 kg/tree) and is to be avoided. Return bloom was not fully acceptable for all treatments except on those trees on which flowers were thinned to 25%. Fruit quality parameters: bright yellow background skin colour, red surface skin colour and soluble solids content increased significantly with reduced crop load. Fruit acidity was not significantly affected by any treatment. Flower thinning to 50% of full bloom or fruitlet thinning up to 50% had the greatest positive effect on fruit size; yield, fruit quality and return bloom compared to the unthinned control and future investigations should examine the impact of these over a longer time period (Meland et al. 2016).

Table 2. Effects of different crop loads on fruit set, yield and fruit quality of 'Opal 'plums in 2008 and return bloom in 2009. (Source: Meland et al., 2016).

Crop level	Fruit set[y] (%)	Yield per tree (kg)	Fruit weight (g)	Soluble solids (%)	Firmness (Durofel)	Back ground colour (1-9)	Acid (%)	Return bloom 2009
Unthinned	63.1 c[z]	53.4 c	30.9 a	12.6 a	75.1 b	6.9 a	1.3 a	97.7 a
50% flowers	40.5 b	38.0 ab	38.7 b	13.0 a	72.4 ab	7.5 ab	1.3 a	162.2 b
25% flowers	17.5 a	23.2 a	40.0 b	14.6 b	72.6 ab	8.2 b	1.3 a	261.5 c
50% fruitlets	39.6 b	42.8 bc	38.4 ab	13.2 ab	69.9 a	8.0 b	1.2 a	159.5 b
25% fruitlets	31.4 b	36.5 ab	41.8 b	14.0 ab	72.1 ab	7.8 ab	1.3 a	162.7 b
SE	10.67	10.59	5.76	0.97	3.40	0.79	0.09	32.74

[y] Expressed as % of initial number of flowers per tree.
[z] Means followed by the same letter are not significantly different at P < 0.05 according to Tukey's test.

Chemical thinning of fruitlets

Chemical thinners are used to stimulate increased fruitlet abscission. The ideal chemical fruitlet thinner would be one that can be applied once the degree of natural fruit set is established and the abscission is complete. Growth of the pericarp of plums follows a double sigmoid curve. A rapid initial growth (Stage I) is followed by a shorter and slower phase when the seeds are developing (Stage II) followed by another phase with rapid pericarp growth which last until harvest (Stage III). Most trials have shown that sprays applied for fruitlet thinning are the most effective when applied during Stage II and is referred to early pit hardening (Webster and Spencer, 2000). Optimum fruitlets size for applying chemical thinning varies depending on the cultivar.

Ethephon

Exogenously applied ethephon stimulates ethylene production, which in turn causes fruit abscission (Wertheim, 2000). Previous evaluations of ethephon on stone fruit at full bloom or two weeks after full bloom with warm weather conditions demonstrated that ethephon is a successful thinning agent (Meland, 2004). However, ethephon thinning results were not always predictable nor consistent (Webster and Spencer, 2000). Usually ethephon performs better as a fruitlet thinner. This may be attributable to the higher temperatures later in the season and/or increased sensitivity of the fruit to ethephon at the later 'pit hardening' stage (Webster and Spencer, 2000). Chemical thinning of blossoms permits reduction of the potential overset at the earliest possible stage, thus reducing the impact on photoassimilate reserves. In Scandinavia, fruit thinning with ethephon at the early bloom stage or lime sulphur at full bloom have been recommended (Kvåle, 1978). A single dilute application of 250 mg/l ethephon at full bloom reduced fruit set and crop load, and increased fruit quality and return bloom of the cultivar 'Victoria' (Meland 2007; Meland and Birken, 2010). However, these chemicals occasionally produce inconsistent results on a commercial scale. Fruit thinning following bloom permits a more exact evaluation of fruit set before any application of a thinning agent. However, most common is that growers prefer to first see fruit set and then determine the need for thinning.

Martin et al. (1975) found that 'French Prune' could be effectively thinned using ethephon spays if applied when the seeds were approximately 8-9 mm long. However, the main problem with these sprays was the inconsistent response from site to site and from season to season. Consequently, warm weather (>15 ºC) at the time of spraying and ethephon concentrations of between 200-250 mg/l appear most appropriate for thinning European plum cultivars. In general this coincides with the fruitlet stage reported by Webster and Spencer (2000). Basak et al. (1993) found that 'Opal' and 'Common Prune' were thinned effectively using 200 mg/l ethephon applied two weeks after flowering and Seehuber et al. (2011) and Weber (2013) using ATS and/or ethephon four weeks after flowering.

In 2007, 2008 and 2009, mature 'Jubileum'/'St. Julien A' trees were treated with ethephon either at full bloom, at concentrations of 250, 375 and 500 mg/L or when fruitlets averaged ~12 mm in diameter at concentrations of 125, 250 and 375 mg/L (Meland and Kaiser, 2017). In general, flower-thinning treatments reduced fruit set significantly (Table 3). Fruit set decreased with increasing ethephon concentrations, and the highest rate of ethephon applied either at full bloom (500 mg/L) or post bloom (375 mg/L) resulted in excessive over-thinning (Table 3). Up to 375 mg/L of ethephon was required at full bloom whereas only 125 mg/L of ethephon was required post bloom to get a noticeable fruitlet thinning. Yields confirmed the fruit set response and yield reductions were significant. In most years, all thinning treatments resulted in fruit larger than 38 mm in diameter compared to fruit from unthinned control trees. Return bloom the following year was mostly unaffected by all ethephon applications compared to the control. In conclusion, an ethephon application at a rate of up to 375 mg/L applied at full bloom will result in adequate thinning of 'Jubileum' plums and achieved a target of about 10-15% reduction in fruit set. When weather conditions are not conducive during flowering, a post bloom ethephon application at 125 mg/L may be applied. However, this should only be considered in years of excessive flowering and as a last resort.

Table 3. Effects of different ethephon concentrations applied in 2007 at full bloom or post bloom on trunk cross sectional area (TCSA), fruit set, yield, fruit weight and return bloom of ‘Jubileum’ plum in Ullensvang, Norway. (Source: Meland and Kaiser, 2017)

Ethephon concentration (mg/L)	TCSA (cm^2)	Harvested fruit /100 flowers	Yield (kg/tree)	Fruit weight (g)	Flowers/ branch in 2008
0 control	29.0	21.4	21.5	40.0	149
250 full bloom	27.0	19.8	20.8	43.5	141
375 full bloom	27.9	14.2	14.2	50.9	147
500 full bloom	29.5	6.8	7.4	54.2	153
125 post bloom	28.2	16.3	13.0	40.1	130
250 post bloom	30.2	14.6	12.3	42.1	145
375 post bloom	30.9	2.4	1.5	46.6	123
Significance	NS	***	***	***	NS
LSD (P = 0.05)	4.06	6.9	5.0	7.3	-

ACC

A new chemical thinner currently being evaluated in pome fruit is 1-aminocyclopropane-1-carboxylic acid (ACC) (Schupp et al., 2012). According to Adams and Yang (1979), ACC is effectively converting to ethylene in apple tissue. Further studies on mung beans confirmed that ACC, a precursor of ethylene, increased the corresponding rate of ethylene production (Yoshii and Imaseki, 1981).

A study was conducted to evaluate this new chemical thinning strategy on ‘African Rose™’. The chemicals evaluated were 1-aminocyclopropane-1-carboxylic acid (ACC) at 150, 300 and 500 µL/L in the 1st season and 400, 600 and 800 µL/L in the 2nd season, and 6-benzyladenine (6-BA) at 100 or 300 µL/L in the 1st season and 100 µL/L in the 2nd season. 6-BA was included to prevent ACC-induced leaf drop. ACC was also combined with mechanical thinning utilizing the Darwin 300™ and hand thinning during bloom included as treatment. All the foliar applications were made when the average fruitlet size was 8 - 10 mm. ACC consistently reduced the commercial hand thinning requirement in both seasons. In the second season, there was a linear decrease in yield efficiency as the ACC rate increased, while a quadratic response was seen in fruit size with the two higher rates inducing larger but similar fruit size.

Brevis®

Inhibition of photosynthesis by the new fruit thinning agent Brevis® containing metamitron as active ingredient has been shown to be a very effective thinning agent in apple (Brunner, 2014) and pear (Maas and Steeg, 2011; Stern, 2014, 2015) with good thinning efficacy in the both cooler Norwegian (Maas and Meland, 2016) and warmer Israelian growing conditions (Stern, 2014, 2015). Unfortunately Brevis® cannot be used for thinning plum as it causes strong phytotoxicity symptoms in the leaves without any significant fruit thinning (Fig. 6, Maas, personal observation).

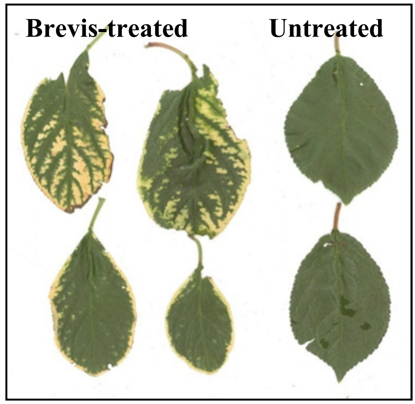

Figure 6. Leaf phytotoxicity symptoms 'Victoria' plum treated with 2.3 kg/ha Brevis® on May 20, 2010. (Photo's: Frank Maas, September 8, 2010).

Factors affecting the results of chemical thinning

The results of chemical thinning are greatly influenced by climatic conditions around the time of spraying, the efficiency of spaying application, spray additives and water pH. In general high temperature and pH favour the effect of thinning. Other factors are floral abundance and other tree factors like tree vigour. The health status of the tree including the nutritional levels has to be considered before applying a thinning agent. Alternate bearing trees in their 'on year' are more difficult to thin than in the 'off year'.

Conclusion

There is an increasing market demand for large plums with good flavour and colour and high sugar content in the market. Except breeding new cultivars which produce optimum numbers of fruit without need for thinning, there is a strong need for methods of regulating the crop load of the traditional cultivars. Manual thinning is too costly to be economically achievable and can be used only as a supplement to chemical thinning. Different thinning concepts are available from mechanical thinning to chemical thinning during bloom or at fruitlet stages. A common approach is to use mechanical thinning and chemical thinning first followed by fine adjusting by hand. Many factors affect the final results of thinning practices and chemical thinning is one of the most demanding cultural practices a grower is conducting in order to get the fruit set level and fruit quality to its target values.

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Predavanje po pozivu

PRIMENA BIOREGULATORA U CILJU POBOLJŠANJA KVALITETA I SKLADIŠNE SPOSOBNOSTI PLODOVA

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Izvod. Bioregulatori mogu dati značajan doprinos poboljšanju kvaliteta ploda i produžavanju mogućnosti skladištenja. Značajni ciljevi u ogledima sa bioregulatorima u Istraživačkom centru Haidegg (Grac, Austrija), u poslednjim godinama bili su ispitivanje njihovog uticaja na smanjivanje rasta, sprečavanje alternativne rodnosti, poboljšanje kvaliteta ploda (boja, krupnoća, unutrašnji kvalitet) i produžavanje mogućnosti skladištenja plodova. Upotreba bioregulatora u konceptu integralne proizvodnje ne može otkloniti ozbiljne greške u proizvodnji voćaka kao što su pogrešan izbor lokacije, podloge i sorte, loš sadni materijal, neodgovarajuća rezidba, neredovna zaštita voćaka, pogrešan termin berbe itd. Dozvola za upotrebu aktivne materije 1-metilciklopropen (1-MCP), posle uvođenja CA tehnologije u proizvodnju šezdesetih godina, je bila prekretnica u austrijskoj tehnologiji hlađenja. Poboljšanje čvrstoće, osnovne boje i sadržaja kiselina omogućava ponudu plodova sa boljim ukusom, naravno ako je berba izvedena u optimalnom terminu za sortu. Plodovi sorti koje su sklone brzom smanjivanju čvrstoće plodova (Elstar, Rubinette, Jonagold) mogu se sa uspehom skladištiti duže vreme. Kod sorti koje su posebno osetljive na posmeđivanje pokožice (Granny Smith i Crveni delišes) kroz upotrebu 1-MPC proizvodnja ponovo doživljava renesansu uzimajući u obzir da u Austriji u plodovima posle skladištenja ne sme biti ostataka (rezidua) preparata. Pored mogućnosti kvalitetne proizvodnje, proizvodači u Austriji sa 1-MCP imaju na raspolaganju preparat, sa kojem mogu minimizirati gubitke u kvalitetu plodova u skladištu i produžiti skladišnu sposobnost.

Ključne reči: bioregulatori, jabuka, opadanje plodova, kvalitet ploda, skladištenje.

Uvod

Osnova za dobar kapacitet skladištenja i kvalitet plodova su potpuno razvijeni plodovi u optimalnom stanju zrelosti. Potpuno razvijeni plodovi podrazumevaju spoljašnji izgled plodova (potpunu morfološku razvijenost – veličina, oblik, boja) i sadržaj određenih supstanci (puna biohemijska razvijenost). Visok nivo hemijskih materija kao što su šećeri, kiseline itd. je garancija za odličan ukus posle skladištenja, ako su plodovi bili ubrani u optimalnom terminu berbe i hlađeni u najboljim uslovima. Uspeh skladištenja plodova u velikoj meri zavisi od predberbenih faktora (Tabela 1). Skladištenjem plodova možemo očuvati kvalitet plodova, ali ga ne možemo poboljšati.

Tabela. 1. Faktori koji utiču na kvalitet i čuvanje plodova.
Factors that influence fruit quality and sorage.

Ekološki faktori *Ecological factors*	Fiziološki faktori *Physiological factors*	Stanje plodova u vreme berbe *Fruits condition at harvest time*	Uslovi čuvanja *Storage conditions*
Lokacija (nadm. visina)	Opterećenje stabla (proređivanje plodova)	Zrelost plodova (optimalni termin berbe)	Temperatura
Temperatura	Snabdevanje mineralima kroz đubrenje (Ca, K, Mg, N i dr.)	Snabdevanje mineralima (Ca)	Cirkulacija vazduha
Sunčani sati	Starost voćnjaka	Krupnoća plodova	Sastav atmosfere (O_2, CO_2, C_2H_4)
Snabdevanje vodom	Osvetljenost	Obojenost plodova	Tretiranja posle berbe (Ca, topla voda, 1-MCP)
Tip zemljišta	Rast mladara (regulisanje rasta)	Hemijski sastav (šećeri, kiseline, vitamin C)	
	Stanje listova	Bioregulatori protiv opadanja plodova pre berbe, kasnija berba (NAA, AVG, 1-MCP)	

Sa finansijsko-proizvodnog aspekta treba skladištiti samo visokokvalitetne i dobro održive plodove. Bioregulatori se koriste pre berbe (četiri nedelje pre prognozirane berbe) u cilju smanjivanja opadanja plodova ili za kontrolu sazrevanja plodova (Tabela 2). Kod jabučastog voća (jabuka, kruška) se koristi α-naftilsirćetna kiselina (NAA) za sprečavanje opadanja plodova. Preparati sa aktivnim materijama aminoetoksivinilglicin (AVG) i 1-metilciklopropen (1-MPC) se koriste kod svih vrsta klimaterijskog voća za kasnije izvođenje berbe. Za usporavanje sazrevanja plodova se koristi i giberelinska kiselina (GA_3), uglavnom kod koštičavog voća. U suprotnom pravcu, etefon ubrzava sazrevanje plodova. Njegova upotreba je značajna na parcelama gde gajimo plodove za brzu upotrebu, kao što su plodovi za preradu, npr. industrijske parcele pripremljene za mehanizovanu berbu.

Bioregulatori za sprečavanje opadanja plodova

Za sprečavanje opadanja plodova su u mnogim evropskim zemljama registrovane aktivne materije iz grupe auksina (NAA, NAAm). U Nemačkoj je i aktivna materija trihlopir (trgovački naziv Topper) registrovana za poboljšanje održavanja plodova pre berbe (Baab i Lafer, 2005). Za poboljšanje održavanja plodova upotrebljava se biljni aktivator 1-triptofan – prirodna amino kiselina, koja je prekursor auksina. U mnogim zemljama se dosta koriste inhibitori etilena AVG i 1-MCP, koji za vreme sazrevanja plodova inhibiraju dejstvo etilena. 1-MCP u obliku preparata Harvista se upotrebljava za sprečavanje opadanja plodova i za kasnije izvođenje berbe. Za upotrebu posle berbe 1-MCP u obliku preparata Smartfresh je dozvoljen u velikom broju zemlja.

Tabela. 2. Bioregulatori za regulisanje sazrevanja i poboljšanje kvaliteta skladištenja plodova.
Bioregulators for regulation of fruit maturation and fruit storage quality.

Aktivna materija *Active ingredient*	Trgovački naziv *Trade name*	Sadržaj a.m. *Content of a.i.*	Polje dejstva *Field of action*	Vrsta voćaka *Fruit species*	Svrha *Purpose*
NAA	Fruitone, Obsthormon 24a	75 g/l, 84 g/l	Regulisanje prinosa, zadržavanje rasta	Jabuke, kruške	Proređivanje plodova, smanjenje opadanja plodova pre berbe
GA_3	Berelex, Gibb 3	10%	Regulisanje rasta, prinosa i sazrevanja plodova	Kruške, koštičavo voće	Diferenciranje cvetnih pupoljaka, kasnije zrenje koštičavog voća
Etefon	Cerone, Ethrel, Flordimex 420	660 g/l, 480 g/l, 420 g/l	Regulisanje rasta, prinosa i sazrevanja plodova	Jabuke, kruške, koštičavo voće	Povećava diferenciranje cvetnih pupoljaka, ubrzava zrenje plodova
AVG	ReTain	4,15-15%	Regulisanje diferenciranja cvetnih pupoljaka i sazrevanja plodova	Jabuke	Povećava diferenciranje cvetnih pupoljaka, kasnije sazrevanje plodova
1-MCP	Harvista, SmartFresh, Fysium	1,3%, 3,3%, 97,65%	Regulisanje sazrevanja plodova	Jabučasto voće	Manje opadanje plodova pre berbe, kasnije zrenje, pre i posle berbe

Auksini sprečavaju opadanje plodova tako što sprečavaju stvaranje sloja za odvajanje između peteljke i ploda. U jesen se smanjuje prirodna sinteza auksina u plodovima. Ovo vodi stvaranju sloja za odvajanje u osnovi peteljke i rezultat toga je opadanje plodova. Kroz tačno ciljano prskanje sintetičkim auksinima (NAA, NAAm, 3,5,6-TCP) nadoknađuje se manjak prirodne sinteze auksina i tako se sprečava formiranje sloja za odvajanje, a time i opadanje plodova. Suprotno tome, Etilen forsira izgradnju tkiva za odvajanje i kod upotrebe ethefona za proređivanje ili za ubrzavanje sazrevanja plodova u jesen jako se povećava opadanje plodova. NAA se primenjuje u proseku 12 do 14 dana pre planirane berbe, a najkasnije kad opadnu prvi plodovi. Moguće je mešanje sa fungicidima ili preparatima kalcijuma koji sprečavaju pojavu gorkih pega. NAA sprečava opadanje plodova, ali ima i negativnu stranu da kroz proces sazrevanja ubrzava sintezu etilena. Problemi koji mogu nastupiti kroz endogenu produkciju etilena su:

- Rano i brzo sazrevanje,
- Brže starenje plodova u hladnjači (intenzivnije disanje),
- Manja čvrstoća mesa plodova,
- Brža razgradnja hlorofila (rumeni Zlatni delišes),
- Skraćeno vreme čuvanja plodova u hladnjači.

U Austriji je preparat Fruitone sa aktivnom materijom α-naftilsirćetna kiselina (NAA) iz grupe auksina registrovan za sprečavanje opadanja plodova. Primenjena količina zavisi od sorte i varira od 0,15 do 0,2 L/ha.

Aminoetoksivinilglicin (AVG) je otkriven u kasnim sedamdestim godinama pod pokroviteljstvom firme Hoffman LaRoche. Aktivna materija je prirodna aminokiselina. U poslednjih 20 godina sa AVG postavljen je veliki broj ogleda. AVG je od 1995. godine pod okriljem Abbott Laboratories (Valent Bio Sciences) na tržištu raširen pod imenom Retain™ (sadržaj aktivne materije AVG 4,15-15%) u brojnim zemljama kao što su: SAD, Čile, Argentina, Južna Afrika, Novi Zeland. AVG je registrovan za smanjenje opadanja plodova jabuke i kruške pre berbe. U Evropskoj Uniji je proces registracije, iniciran od strane firme Valent, zaustavljen zbog novih strogih procesa registracije od strane homologacijskih organa.

Aktivnost AVG zasniva se na inhibiranju sinteze enzima koji je odgovoran za pretvaranje S-adenozilmetionina (SAM) u 1-aminociklopropan-1-karboksilnu kiselinu (ACC) koja je prekursor etilena. Polazna materija za biosintezu etilena je aminokiselina metionin. Etilen je jedini poznati fitohormon koji je kao gas fiziološki aktivan. Njegove najvažnije biološke aktivnosti su ubrzavanje sazrevanja plodova, staranja, opadanja lišća i plodova.

Tabela 3. Poređenje uticaja NAA i AVG.
Comparison of influence of NAA and AVG.

Uticaj / *Influence*	AVG	NAA
Opadanje plodova	+	+
Čvrstoća mesa ploda	+	–
Staklavost ploda	+	–
Posmeđivanje pokožice	+	–
Mogućnost produženja skladištenja	+	–
Proizvodnja etilena	–	+

Bangerth (1978) i Halder-Doll i Bangerth (1987) navode rezultate o izvanrednom uspehu sprečavanja opadanja plodova kod upotrebe AVG mesec dana pre planiranog temina berbe. Učinak sprečavanja opadanja plodova bio je isti kao kod NAA, ali je uporedo sa NAA pokazao puno drugih prednosti (Tabela 3), kao što je usporavanje sazrevanja plodova preko inhibiranja sinteze etilena. Takođe, kod upotrebe AVG pre berbe može se primetiti značajano povećanje čvrstoće mesa ploda. Stoga se AVG može upotrebiti kao obećavajuće sredstvo u tehnologiji voćarske proizvodnje u kontroli opadanja plodova i poboljšanju njihovog kvaliteta za vreme berbe. Dok se aplikacijom auksina (NAA) često stimuliše proizvodnja etilena i time ubrzava sazrevanje plodova, upotrebom AVG se postiže kontra efekat - znači bolji kvalitet plodova za duže skladištenje. Tretiranje plodova sa AVG zadržava hormonski indukovano opadanje plodova i sprečava skoro u potpunosti autokatalitičku sintezu etilena u plodovima. Rezultat smanjene sinteze etilena je znatno veća čvrstoća plodova posle skladištenja.

Upotreba 1-MCP (Harvista) pre berbe.

Harvista je trgovačko ime za 1-MCP, koji se upotrebljava za prskanje voća pre berbe. 1-MCP blokira procese sazrevanja tako što spaja receptore etilena sa ćelijskim mebranama biljke i time čini etilen neaktivnim. Tretiranje preparatom Harvista usporava razlaganje skroba, omekšavanje plodova, razvoj crvene boje, opadanje plodova pre berbe i može sprečiti ili odložiti pojavu staklavosti plodova. Ovaj preparat možemo upotrebiti blizu predviđenog termina berbe (tri dana pre berbe). Sazrevanje plodova se može odvijati normalno i tretiranje možemo obaviti tačno pre početka berbe bez neželjenih efekata. Harvista se ne upotrebljava na stablima u stresnoj situaciji. Efekat upotrebe Harviste sa drugim inhibitorima nije dovoljno istražen. Harvista je često aplicirana linijskim injektor sistemom, a u SAD i helikopterom (Vriends, 2012). Harvista prouzrokuje usporavanje sazrevanja plodova, koje rezultira kasnijim izvođenjem berbe od 7 do 14 dana. Zakašnenje zavisi od sorte, stanja voćnjaka i ciljeva proizvođača. Zakašnjenje sazrevanja ima neke prednosti: bolju organizaciju berbe, redukciju opadanja plodova pre berbe, redukciju sinteze etilena u plodovima, dodatno vreme za razvoj boje i krupnoće plodova, održavanje čvrstoće plodova, usporavanje hidrolize skroba i pojave staklavosti plodova, poboljšanje skladišne sposobnosti plodova.

Upotreba 1- MCP (Smartfresh) posle berbe.

1-MCP zauzima etilen receptore biljke i tako zadržava procese sazrevanja, a takođe deluje i kada se hormon sazrevanja etilen proizvodi ili se nalazi u vazduhu. Iz ovoga rezultira usporavanje sazrevanja koje prouzrokuje dužu mogućnost skladištenja plodova, što funkcioniše kod svih klimakterijskih vrsta voća (jabuka, kruška i dr.). 1-MCP ima mogućnost da značajno minimizira smanjenje čvrstoće plodova, zadržava degradaciju kiselina i zelene boje. Upotreba ove nove aktivne materije uglavnom služi tome da poboljša unutrašnji kvalitet plodova posle hlađenja i da se izbegnu nepovoljne fiziološke promene plodova. Mnoge fiziološke promene plodova pozrukovane staranjem plodova i iduciranjem etilena, kao što su posmeđivanje pokožice i semene kućice plodova, mogu se sprečiti sa 1-MCP (Lafer i Zanella, 2004). Takođe, mnoge skladišne bolesti, kao što je *Neofabraea* ssp. mogu se minimizirati kroz usporavanje sazrevanja pozrukovano sa 1- MCP. 1- MCP pod trgovačkim imenom EthylBloc® se upotrebljava za rezano cveće, a SmartFresh® (Dow AgroSciences) za voće i povrće. U Austriji je SmartFresh® od 2004. godine dozvoljen za upotrebu kod jabuke. 2016. godine je dobio dozvolu za upotrebu alternativni proizvod belgijske firme Janssen Pharmaceutica pod trgovačkim imenom Fysium. Hemijski, 1- metilciklopropen je gasovita supstanca sa formulom C_4H_6. SmartFresh® je formulisan kao prašak, a Fysium kao tečnost. Upotrebljava se kao sredstvo za zamagljivanje ćelija na sobnoj temperaturi (12 sati) ili hlađenih ćelija (24 sata). 1-MCP se upotrebljava u gasovitom obliku u jako niskoj koncentraciji 0,625 μ/L (625 ppb), nema rezidua i njegova upotreba je laka.

Rezultati ogleda sa bioregulatorima u cilju poboljšanja kvaliteta ploda i produžavanja skladištenja

Eksperiment 1. Sprečavanje opadanja plodova pre berbe kod sorte jabuke Arlet.

U određenim godinama kod nekih sorti jabučastih voćaka dolazi do velikih gubitaka prinosa zbog opadanja plodova pre berbe. U Austriji je za ovakve slučajeve dozvojen auksin NAA u obliku tgovačkog preparata Late Val (10% aktivne materije). U bližoj budućnosti se može očekivati ukidanje proizvoda na bazi NAA sa tržišta. Zbog toga je potrebno kod odabranih sorti jabučastih voćaka testiranje alternativnih proizvoda, kao što su AVG i aminokiselina 1-triptofan na različitim lokacijama sa ciljem smanjenja opadanja plodova pre berbe. Cilj eksperimenta je bio testirati efekt AVG, NAA i 1-triptofana na opadanje plodova pre berbe i kvalitet ploda kod sorte jabuke Arlet.

Materijal i metode rada

Lokacija: Farma Erlacher, Wolfgruben kod Gleisdorfa
Voćna vrsta: Jabuka
Sorta: Arlet
Podloga: M9
Sistem sadnje: jednoredni - protivgradna mreža; 3,5 m × 1 m (2857 stabla/ha)
Uzgojni oblik: usko vitko vreteno
Datum berbe: 14.09.2004.
Skladištenje: normalna (NA) + kontrolisana atmosfera (CA)
NA: temperatura 1,2°C (do 20.11.2004)
CA: temperatura 2,5°C, CO_2 i O_2 po 2,0%
Vađenje iz hladnjače: 18.05.2005.
Rok trajanja plodova (shelf life): 30.05.2005. na 20°C

Varijante ogleda

1. Kontrola (bez prskanja)
2. AVG - 125 ppm: Retain 0,3% (3 kg/ha) + okvašivač 0,1%, 1× tri nedelje pre optimalnog termina berbe; upotreba vode od 1000 l/ha
3. 1-triptofan - 50 ppm: Platina (Glob 20) 0,1%,1× tri nedelje pre optimalnog termina berbe
4. NAA - 15 ppm: Luxan Lateval 0,015% (150 ml/ha), upotreba 1× tri nedelje pre optimalnog termina berbe

Rezultati

Rezultati eksperimenta pokazuju signifikantnu redukciju opadanja plodova kod upotrebe AVG i triptofana. AVG pouzrokuje kašnjenje berbe za oko nedelju dana u poređenju sa kontrolom (tabela 4), što se može videti po skrobnom indeksu (7,1 do 8,6 u kontroli) i indeksu sazrevanja po Štrajfu (0,09 do 0,07 u kontroli).

Tabela 4. Opadanje plodova, opterećenje, kvalitet ploda i zrelost plodova u vreme berbe.
Fruit drop, crop load, fruit quality and fruit maturity at harvest.

Varijante *Variants*	Opali plodovi *Fruit drop* (kg)	Broj plodova *No. of fruits*	Prinos po stablu *Yield per tree* (kg)	Masa ploda *Fruit weight* (g)	Dopunska boja ploda *Fruit overcolor* (%)	Skrobni indeks *Starch index* (1-10)	Štrajfov indeks[1] *Streif index*
Kontrola	3,0 a	62,3 b	13,0 a	206,8 b	60,1 ab	8,6 a	0,07 a
AVG 125 ppm	1,2 ab	74,8 a	14,1 a	189,6 a	49,3 a	7,1 b	0,09 b
1 - triptofan 50 g/l	0,8 b	72,9 ab	14,6 a	201,6 ab	52,0 a	8,2 a	0,08 ab
NAA 15 ppm	2,2 ab	74,0 a	14,9 a	200,9 ab	58,6 b	8,7 a	0,07 a
Prosek	1,8	71,0	14,2	199,7	57,5	8,2	0,08
LSD 5%	2,5	12,12	3,12	13,49	13,26	0,72	0,01

[1]Štrajfov indeks - Čvrstoća plodova (kg/cm^2) × Skrobni indeks / Šećeri (°Brix).
Streif index – Fruit firmness (kg/cm^2) × Starch index / Sugars (°Brix).

Udeo crvene boje kod primene AVG i triptofana je bio signifikantno niži. Čvrstoća plodova je bila kod svih varijanti za vreme berbe visoka i najstabilnija kod primene AVG i triptofana (tabela 5). U sadržaju suve materije (šećera) i jabučne kiseline za vreme berbe nije bilo signifikantnih razlika između varijanti ogleda. Najniži sadržaj jabučne kiseline i čvrstoće plodova posle Shelf-life testa imali su plodovi iz varijante tretirane NAA (1,9 gL^{-1}). Ovo je dokaz da NAA ubrzava sazrevanje plodova.

Tabela 5. Dinamika smanjenja čvrstoće plodova i sadržaja jabučne kiseline.
Dynamics of decresse of fruit firmness and the content of malic acid.

Varijante *Variants*	Čvrstoća ploda *Fruit firmness* (kg/cm^2)				Jabučna kiselina *Malic acid* (g L^{-1})			
	Berba[1] *At harvest*	MS[2]	PS[3]	SL[4]	Berba *At harvest*	MS	AS	SL
AVG 125 ppm	7,4	5,3	5,5	4,3	7,0	4,7	3,1	2,1
1-triptofan 50 g/l	7,6	5,8	5,6	4,8	7,1	4,9	3,2	2,3
NAA 15 ppm	7,3	6,1	4,9	4,7	7,3	5,3	3,3	2,3
Prosek	7,3	5,4	5,2	4,0	6,9	4,4	3,0	1,9
AVG 125 ppm	7,4	5,7	5,3	4,5	7,1	4,8	3,1	2,2
SX	0,12	0,37	0,33	0,4	0,19	0,38	0,15	0,21

[1]Berba / *Harvest* - 14.09.2004.
[2]MS – U toku skladištenja / *During cold storage* - 21.03.2005.
[3]PS – Posle skladištenja / *After cold storage* - 18.05.2005.
[4]SL – Nakon 7 dana na 20°C / *Shelf life (7 days at 20°C).*

Plodovi koji su bili tretirani su imali i najveću pojavu mekih opekotina (Soft Scald) za oko 10% više nego kod kontrole. Suprotno tome, AVG je uticao na smanjenje pojave mekih ožegotina za 30% u poređenju sa kontrolom. Zrelost plodova odlučujuće utiče na intenzitet nastupanja ove fiziološke skladišne bolesti.

Zreliji plodovi su osetljiviji na niske temperature i pokazuju više simptoma mekih ožegotina u hladnjači (tabela 6).

Tabela 6. Pojava i intenzitet mekih ožegotina po kategorijama (% plodova sa simptomima) posle dugog skladištenja (240 dana) + shelf life (7 dana na 20°C).
The occurrence and intensity of Soft Scald by category (% of fruit with symptoms) after long storage (240 days) + shelf life (7 days at 20°C)

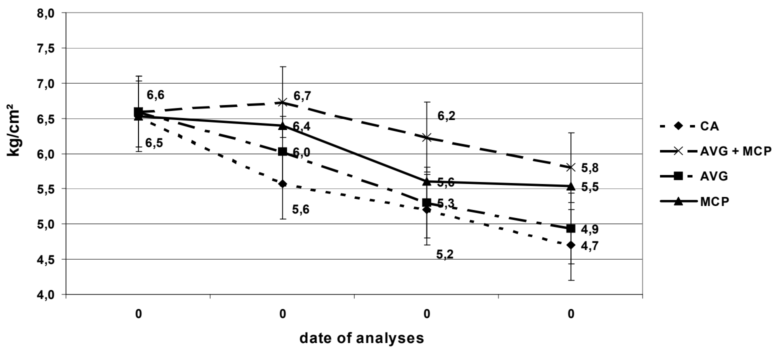
Varijante	Posle čuvanja / *After storage*					*Shelf life*			
Variants	0%	1-10%	11-20%	21-30%	>30%	0%	1-10%	11-30%	>30%
AVG 125 ppm	68,6	14,7	8,0	5,9	2,8	68,6	14,7	13,9	2,8
1-triptofan 50 g/l	100,0	0,0	0,0	0,0	0,0	100,0	0,0	0,0	0,0
NAA 15 ppm	63,7	14,3	6,9	6,6	8,5	63,7	14,3	13,5	8,5
Prosek	58,3	11,6	7,9	8,8	13,5	58,3	11,5	16,7	13,5
AVG 125 ppm	72,6	10,1	5,7	5,3	6,2	72,6	10,1	11,0	6,2
SX	18,72	6,9	3,84	3,75	6,03	18,72	6,9	7,49	6,03

Eksperiment 2. Skladišni kapacitet i kvalitet plodova Zlatnog delišesa u zavisnosti od termina berbe i tretiranja sa AVG i 1-MCP.

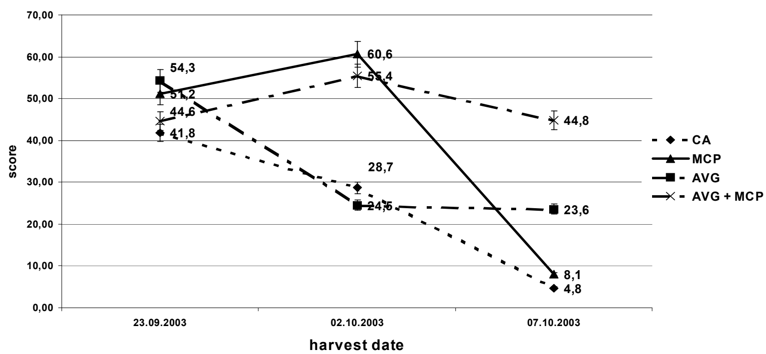
U istraživačkom centru Haidegg na sorti Zlatni delišes je praćen efekat primene preparata AVG upotrebljenog pre berbe i 1-MCP upotrebljenog posle berbe. Plodovi su bili skladišteni u kontrolisanoj atmosferi (CA). Preparat Retain™ (15% a.m.) je bio je korišćen kao izvor AVG. Upotrebljen je u dozi od 125 ppm četiri nedelje pre očekivane berbe (OB). Plodovi su bili skladišteni u tri različite faze sazrevanja (OB, OB + 1 nedelja, OB + 2 nedelje). Svaka faza podeljena je na dva dela (sa oko 40 kg plodova). Prvi deo je bio tretiran sa 1-MCP (625 ppb), dok je drugi deo ostao netretiran (kontrola). Plodovi su čuvani u CA hladnjači na temperaturi od 1,0°C, sa 1,5% O_2 i 3,5% CO_2 u periodu od 270 dana.

AVG prouzrukuje zakašnjenje berbe za 7 dana i zaustavlja procese sazrevanja plodova u uslovima CA skladišta. U varijanti bez AVG i 1-MCP plodovi pokazuju preteran gubitak čvrstoće i titracione kiselosti za vreme roka trajanja (shelf life). AVG i 1-MCP odlažu omekšavanje plodova (slika 1) i stabilizuju titracione kiseline. Ovaj efekt se odnosi na sazrevanje plodova i značajan sinergetski efekat AVG i 1-MCP se može primetiti kod kvaliteta ploda. Prekasno ubrani plodovi u hladnjači više gube čvrstoću i kiseline u odnosu na plodove ubrane u optimalnom terminu sazrevanja. Primećuje se i pozitivan efekt AVG i 1-MCP na nivo ukupne suve materije (šećera).

Truljenje plodova, oštećenja zbog CO_2, starosno posmeđivanje su bolesti koje su glavni problem posle dugog hlađenja plodova. 1-MCP ima sposobnost da značajno redukuje trulež kroz proces sazrevanja plodova. Ako su plodovi ubrani prekasno, 1-MCP ima jako mali učinak ili je bez efekta. AVG snažno redukuje trulež plodova (od 18,4% do 3,4%), kod kasnijeg sazrevanja plodova. Prekasno ubrani plodovi tretirani sa 1-MCP dodatno pokazuju veću osetljivost na bolesti posmeđivanja plodova (pokožice, mesa plodova i semene kućice). Ovakvi plodovi moraju biti isključeni iz tretiranja sa 1-MCP. Plodovi tretirani sa 1-MCP za vreme sazrevanja više su osetljivi na visoke koncentracije CO_2 nego netretirani plodovi.



Slika 1. Efekat AVG i 1-MCP tretiranja na čvrstoću plodova Zlatnog delišesa u toku CA skladištenja (prosek poslednja tri termina berbe: OB, OB+1, OB+2).
Effect of AVG and 1-MCP treatments on firmness of Golden Delicious fruits during CA storage (average of the last 3 picking dates, OHD, OHD +1, OHD+2).



Slika 2. Efekat AVG i 1-MCP tretiranja na senzoričko ocenjivanje kvalteta ploda Zlatnog delišesa za poslednja tri termina berbe (OB, OB+1, OB+2)
Effect of AVG and 1-MCP treatments on sensoric evaluation of fruit quality of Golden Delicious of the last 3 picking dates (OHD, OHD +1, OHD+2).

Rezultati testova senzoričke evaluacije pokazuju sinergetski efekat AVG i 1-MCP tretiranja. Posle dugotrajnog vremena skladištenja, senzorički kvalitet plodova iz termina kasne berbe je bilo neadekvatan (loš); sa izuzetkom plodovi tretiranih sa AVG i 1-MCP koji su senzorički ocenjeni pozitivno (slika 2).

Eksperiment 3. Optimalni termin berbe i poboljšanje mogućnosti skladištenja kod sorte jabuke Gala (Lafer, 2010).

Sorta jabuke Gala pokazuje osetljivost na dužinu skladištenja. Sa produžavanjem vremena skladištenja plodova rastu problemi održavanja kvaliteta (mala čvrstoća plodova, posmeđivanje pokožice, truleži plodova), koji su često povezani sa vađenjem plodova iz hladnjače. Posebno su kasno ubrani plodovi osetljivi na ove nepovoljne fiziološke promene. Problem se u poslednje vreme povećava zbog produžavanja skladištenja plodova čak do 12 meseci. U pogledu ovih novih ciljeva postavlja se nova definicija optimalnog vremena berbe sorte Gala. Novom tehnologijom hlađenja možemo produžiti skladištenje Gale za 4 do 6 meseci. Iz ovih razloga već tri godine u istraživačkom centru Haidegg se traži najbolji termin berbe Gale u cilju poboljšanja kvaliteta plodova za duže skladištenje uz pomoč dinamičke atmosfere (Zanella et al., 2005) i uz upotrebu 1-MCP (Smartfresh).

Materijal i metode rada

Lokacija:	Haidegg (Grac)
Voćna vrsta:	Jabuka
Sorta:	Gala Galaxy
Podloga:	M9
Sistem sadnje:	jednoredni - protivgradna mreža; 3,4 m × 1 m (2941 stabla/ha)
Uzgojni oblik:	vitko - usko vreteno
Pravac redova:	SI – JZ
Datum berbe:	14.09.2004

Metode skladištenja:

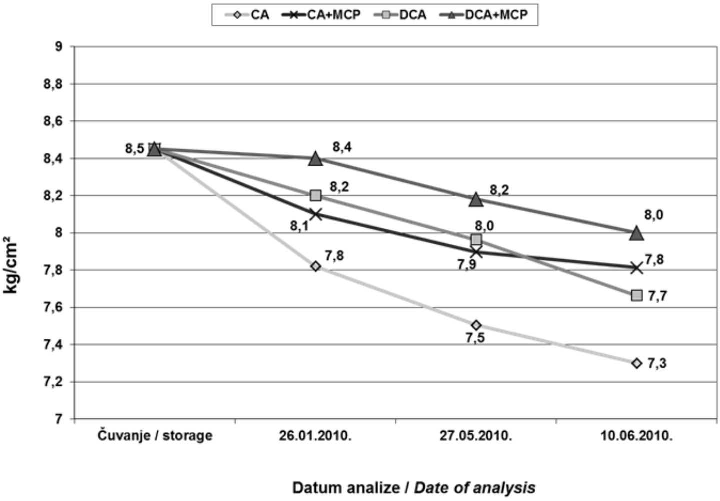
1. CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (I termin berbe)
2. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagođavanje (I termin berbe)
3. CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (I termin berbe) + MCP
4. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagađanje (I termin berbe) + MCP
5. CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (II termin berbe)
6. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagođavanje (II termin berbe)
7. CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (II ermin berbe) + MCP
8. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagođavanje (III termin berbe) + MCP
9. CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (III termin berbe)
10. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagođavanje (III termin berbe)
11. CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (III termin berbe) + MCP
12. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagođavanje (III termin berbe) + MCP

13 CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (IV termin berbe)

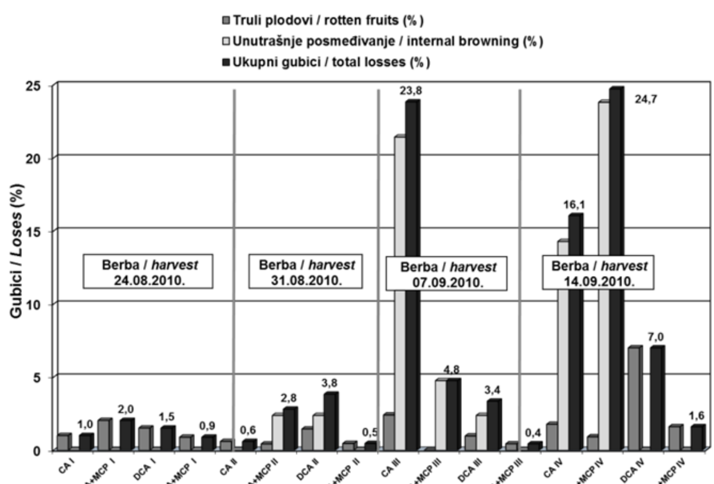
14. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagođavanje (IV termin berbe)
15. CA skladištenje: 1,0°C, CO_2 3,0%, O_2 1,3% (IV termin berbe) + MCP
16. DCA skladištenje: 1,0°C, CO_2 1,5%, O_2 DCA prilagođavanje (IV termin berbe) + MCP

Rezultati

Rezultati ispitivanja skladištenja sorte Gala prikazani su na slikama 3 i 4.



Slika 3. Dinamika smanjenja čvrstoće mesa ploda sorte Gala kod različitih metoda skladištenja (prosek za sve termine berbe).
Dynamics of decresse of flesh fruit firmness of cultivar Gala, with different storage methods (the average for all harvest dates).



Slika 4. Gubici u toku skladištenja (unutrašnje posmeđivanje i propadanje plodova) kod dugog skladištenja plodova sorte Gala.
Losses during storage (internal browning and fruit rot) due to long-term storage of fruits of Gala cultivar.

Zaključak

- Vreme berbe je odlučujući faktor za održavanje kvaliteta i čuvanje plodova u skladištu.
- Kod skladištenja prezrelih plodova ne mogu se postići bolji rezultati DCA hlađenjem i primenom preparata Smart Fresh.
- Optimalno vreme berbe kod sorte jabuke Gala je kraće nego što je bilo dosada (sedam dana).
- Što kasnije beremo plodove, to su veći gubici u skladištenju (za 10% veći između prve i četvrte berbe).
- Kod prekasne berbe se jako povećavaju bolesti posmeđivanja.
- DCA + MCP metode skladištenja minimiziraju bolesti posmeđivanja, i čak i kod prezrelih plodova.
- DCA i CA + MCP su takođe efikasne metode za očuvanje stabilnosti kvaliteta ploda.
- DCA metoda stabilizuje čvrstoću plodova i rok trajanja (Shelf life).
- Efekat na titracionu kiselost plodova postiže se samo sa DCA + MCP metodom.
- DCA+MCP je posebno interesantna metoda skladištenja za malo zrelije plodove (druga polovina optimalnog roka berbe).

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Bioregulators Application in Promoting Fruit Quality and Postharvest Maintaining

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Summary

Bioregulators can make a significant contribution to improving fruit quality and extending the cold storage. Important goals in trials with bioregulators at Research Center Haidegg (Graz, Austria), in recent years have been testing their effects on the reduction of growth, preventing alternative bearing, improve fruit quality (color, size, internal quality) and extension of cold storage of fruits. Use of bioregulators in the concept of integrated production can not remove serious errors in the fruit production, such as the wrong choice of location, rootstocks and cultivars, poor planting material, improper pruning, irregular protection of fruit trees, the wrong dates of picking, etc. Permission to use the active ingredient 1-methylcyclopropene (1-MCP), after the introduction of CA technology in the production of the sixties, was a milestone in Austrian cooling technology. Improving the firmness, ground color and acidity allow to offer fruits with better taste, of course, if the harvest was performed at the optimum time for cultivar. Fruits of cultivars that are prone to rapid reduction of flesh firmness (Elstar, Rubinette, Jonagold) can be successfully stored for a long time. For cultivars that are particularly prone to skin browning (Granny Smith and Red Delicious) through the use of 1-MPC production again experiences a renaissance, taking into account that in Austria the fruits after storage must not contain residues of chemicals. Besides the possibility of high-quality production, producers in Austria with 1-MCP have access to chemical which can minimize losses in fruit quality in storage and extend the storage capacity.

Keywords: bioregulators, apple, preharvest fruit drop, fruit quality, cold storage.

Originalni naučni rad

UTICAJ HEMIJSKOG PROREĐIVANJA PLODOVA NA RODNOST I KVALITET PLODA SORTI JABUKE

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Izvod. U radu je ispitivan uticaj hemijskog proređivanja plodova na zametanje plodova, prinos, kvalitet ploda i povratno cvetanje kod sorti jabuke Zlatni delišes klon Rajnders, Gala rojal bjut, Red kep i Red džonaprins u 2014. godini. Zasad je podignut u proleće 2013. godine sa „knip“ sadnicama. Hemijsko proređivanje je vršeno sledećim sredstvima: naftil-sirćetna kiselina (NAA), 6-benziladenin (6-BA), karbaril, metamitron i kombinacijom ovih sredstava.

Najintenzivnije proređivanje plodova kod svih sorti bilo je kod tretmana sa metamitronom i tretmana sa kombinacijama metamitron + NAA i 6-BA + NAA. Usled smanjenja broja plodova po stablu kod ovih tretmana je zabeleženo najveće povećanje mase ploda u poređenju sa kontrolom. Primena bioregulatora u dvogodišnjem zasadu imala je efekat na cvetanje jabuke narednog proleća. Kod sorti Gala rojal bjut i Red džonaprins, efekat hemijskog proređivanja na cvetanje narednog proleća nije bio značajan, za razliku od sorti Zlatni delišes i Redkep. Kod sorte Zlatni delišes broj plodova preko šest po cm^2 površine poprečnog preseka debla (PPPD) uticao je na izostanak diferenciranja cvetova, dok je kod sorte Red kep kritičan broj plodova bio tri po cm^2 PPPD.

Ključne reči: sorte jabuke, hemijsko proređivanje, zametanje plodova, prinos, krupnoća ploda, povratno cvetanje.

Uvod

Visokointenzivni zasadi jabuke, koji se podižu sa kvalitetnim sadnicama koje imaju sedam i više preveremenih grančica, tokom prve godine diferenciraju veliki broj cvetnih pupoljaka (Keserović i sar., 2013). Veliki broj cvetova može izazvati preobilno zametanje plodova u drugoj godini, što može imati za posledicu usporen rast biljaka, naročito kod spur tipova (Radivojević i sar., 2014), sitniji plod - ispod 70 mm (De Salvador et al., 2006; Treder, 2010) i umanjeno cvetanje naredne godine (Racskó, 2006; Meland, 2009).

Iz tog razloga, već u drugoj godini nakon sadnje, mora se obaviti proređivanje tek zametnutih plodova. Proređivanje plodova može da se obavi ručno, pod uslovom da se zasad nalazi na manjoj površini i da postoji odgovarajuća radna snaga. U slučaju zakasnelog ručnog proređivanja, uprkos ostvarenja zadovoljavajuće krupnoće ploda, može da se javi alternativnost u cvetanju naredne godine (McArtney et al., 1996). Iz tog razloga, hemijsko proređivanje plodova nalazi sve veću primenu i u mladim zasadima.

Hemijsko proređivanje plodova može da se obavi različitim hemijskim sredstvima kao što su sintetički bioregulatori (naftil sirćetna kiselina i 6-benzil adenin), herbicidi (Brevis), insekticidi (Sevin), kao i njihovom kombinacijom. Takođe, uticaj hemijskog proređivanja plodova u velikoj meri je genetski uslovljen (Milatović i sar., 2009, Vulić i sar., 2009), pa je veoma važno ispitivati veći broj sorti.

Upravo iz tog razloga, cilj ovog rada je bio da se utvrdi koje hemijsko sredstvo daje najbolje rezultate u hemijskom proređivanju plodova kod različitih sorti jabuke u drugoj godini nakon sadnje.

Materijal i metode

Zasad je podignut u proleće 2013. godine, u ataru sela Dolova, opština Pančevo. Kao sadni materijal korišćene su dvogodišnje „knip“ sadnice sa preko sedam prevremenih grančica i visinom od 180 cm kod sorti Zlatni delišes (klon Rajnders), Gala (klon Gala rojal bjut) i Džonagold (klon Red džonaprins), a kod sorte Crveni delišes (klon Red kep) korišćene su 18-mesečne sadnice sa preko pet prevremenih grančica. Kao podloga, korišćen je klon podloge M9 T 337, dok je kod sorte Red kep korišćena podloga M 26.

Rastojanje između redova voćaka u zasadu je 3,25 m, a rastojanje u redu kod sorti Zlatni delišes, Gala rojal bjut i Red džonaprins 0,83 m, a kod sorte Red kep 0,71 m. Stabla su oblikovana u formi vitkog vretena. U zasadu su obavljene standardne agro- i pomo-tehničke mere.

Ispitivanja su obavljena tokom 2014. i proleća 2015. godine, odnosno tokom druge i početkom treće vegetacije. Korišćena su sledeća sredstva za proređivanje plodova: sintetički auksin – naftil sirćetna kiselina, NAA (preparat Ormorok) , sintetički citokinin – 6-benziladenin, BA (preparat Globaril 100), insekticid karbaril (preparat Sevin), inhibitor fotosinteze metamitron (preparat Brevis), kao i različite kombinacije ovih preparata (tabela 1). Preparati su korišćeni kada je prečnik centralnog plodića bio između 10 i 12 mm.

Ogled je postavljen po potpuno slučajnom planu. Svaki tretman je bio zastupljen sa po 10 ponavljanja (stabala). Pre primene preparata, određen je ukupan broj cvetnih pupoljaka po stablu, a nakon primene preparata, zametanje plodova (broj plodova/100 cvetova), ukupan broj ubranih plodova, prosečna masa ubranih plodova, širina i dužina plodova, indeks oblika, čvrstoća, stepen obojenosti plodova, ukupna masa ubranih plodova po stablu, broj plodova po cm^2 površine poprečnog preseka debala, kao i ukupan broj cvetnih pupoljaka po stablu u 2015. godini, odnosno trećoj godini nakon sadnje (povratno cvetanje). Osobine ploda određivane su na uzorku od 20 plodova. Površina poprečnog preseka debla je izračunata na osnovu obima debla koji je izmeren na visini od 20 cm iznad spojnog mesta. Čvrstoća ploda je određivana ručnim penetrometrom (FT-327, prečinka 11 mm, Turoni, Italija). Rezultati su statistički obrađeni metodom analize varijanse, a značajnost razlika između srednjih vrednosti određena je pomoću LSD testa na nivou značajnosti od 0,05.

Tabela 1. Trgovački nazivi, aktivne materije i koncentracije korišćenih preparata.
Trade names, active ingredients and concentrations of used chemicals.

Trgovački naziv *Trade name*	Aktivna materija *Active ingredient*	Koncentracija *Concentration* (g, ml/1000 l)
Globaril 100	6- benziladenin (BA)	100
Ormorok	Naftil sirćetna kiselina (NAA)	5
Sevin	Karbaril	650
Brevis	Metamitron	250
Ormorok + Globaril 100	(NAA) + (BA)	5 + 100
Ormorok + Sevin	(NAA) + Karbaril	5 + 650
Ormorok + Brevis	(NAA) + Metamitron	5 + 250

Rezultati i diskusija

Uticaj preparata za hemijsko proređivanje na zametanje i broj plodova prikazan je u tabelama 2 i 3.

Tabela 2. Uticaj hemijskog proređivanja na zametanje i broj plodova kod sorti jabuke Gala i Zlatni delišes.
Influence of chemical thinning on fruit set and the number of fruits in apple cultivars Gala and Golden Delicious.

	Gala rojal bjut (*Gala Royal Beaut*)			Zlatni delišes Rajnders (*Golden Delicious Reinders*)		
Tretman *Treatment*	Broj cvetnih pupoljaka *No. of flower buds*	Broj plodova po stablu *No. of fruits per tree*	Zametanje plodova *Fruit set* (%)	Broj cvetnih pupoljaka *No. of flower buds*	Broj plodova po stablu *No. of fruits per tree*	Zametanje plodova *Fruit set* (%)
BA	52,7	43,8	20,8	98,7*	63,3	16,1
NAA	42,2	32,2	19,1	77,2	44,5	14,9
Karbaril	49,0	40,8	22,0	78,3	53,3	17,6
Metamitron	33,7*	19,5*	14,5*	88,5	23,5*	6,2*
BA + NAA	47,8	22,7*	12,2*	75,0	28,7*	9,5*
Karbaril + NAA	63,2	37,3	15,2*	80,0	35,0	11,6*
Metamitron + NAA	60,7	19,8*	8,5*	79,7	19,2*	6,2*
Kontrola	57,2	49,2	21,3	75,0	43,2	17,1
LSD 0,05	21,4	16,7	5,5	20,5	14,2	5,3

* Zvezdice označavaju srednje vrednosti kod kojih su razlike u odnosu na kontrolu statistički značajne.

Kod sorte Gala rojal bjut, statistički značajno manje zametanje plodova u odnosu na kontolu javilo se prilikom primene metamitrona, kao i prilikom primene preparata NAA u kombinacijama sa BA, karbarilom i metamitronom. Samostalna primena BA, NAA i karbarila nije uticala na smanjenje zametanja plodova. Sličan uticaj na zametanje plodova javlja se i kod sorti Zlatni delišes i Red kep (tabela 3), dok je kod sorte Red džonaprins došlo do smanjenja zametanja i prilikom samostalne primene NAA.

Kod sorte Gala rojal bjut, u poređenju sa kontrolom došlo je do značajnog smanjenja prinosa prilikom upotrebe metamitrona, kao i prilikom kombinovane primene sredstava BA + NAA i metamitron + NAA (tabela 4). Kod ove sorte, statistički značajno krupnije plodove imala su stabla tretirana kombinacijom sredstava BA + NAA, karbaril + NAA, kao i metamitron + NAA. Sličan prinos kod ove sorte prilikom prorede sa karbamilom i kombinacijom NAA i BA dobili su Dusii etl al, 2006, stim što je kod njih plod bio oko 150 g. Kod sorte Gala rojal bjut primena bioregulatora nije uticala na oblik ploda i čvrstoću, dok su se obojeniji plodovi javili kod stabala koji su tretirana kombinacijom metamitron + NAA.

Kod sorte Zlatni delišes prinos se kod tretiranih stabala nije smanjio u odnosu na kontrolu, pre svega zbog povećanja mase ploda. Krupniji plod u odnosu na kontrolu imala su sva tretirana stabla, osim stabala koja su prskana karbarilom.

Tabela 3. Uticaj hemijskog proređivanja na zametanje i broj plodova kod sorti jabuke Red kep i Red džonaprins.
Influence of chemical thinning on fruit set and the number of fruits in apple cultivars Red Cap and Golden Delicious.

Tretman *Treatment*	Red kep (*Red Cap*)			Red džonaprins (*Red Jonae*)		
	Broj cvetnih pupoljaka *No. of flower buds*	Broj plodova po stablu *No. of fruits per tree*	Zametanje plodova *Fruit set* (%)	Broj cvetnih pupoljaka *No. of flower buds*	Broj plodova po stablu *No. of fruits per tree*	Zametanje plodova *Fruit set* (%)
BA	69,2	30,5	11,0	56,3	34,7	16,2
NAA	59,3	20,8	9,2	66,2*	26,2	10,5*
Karbaril	60,3	24,0	10,0	77,7*	40,0	12,9
Metamitron	66,0	11,8*	4,5*	79,3*	15,5*	4,8*
BA + NAA	69,2	14,8*	5,6*	73,0*	20,3*	7,3*
Karbaril + NAA	65,0	17,5*	6,8*	65,7*	18,7*	7,8*
Metamitron + NAA	58,8	9,3*	4,0*	64,0*	12,5*	5,1*
Kontrola	59,8	23,2	9,9	45,5	29,3	16,4
LSD 0,05	11,9	5,3	2,3	14,0	7,2	4,1

* Zvezdice označavaju srednje vrednosti kod kojih su razlike u odnosu na kontrolu statistički značajne.

Kod sorte Red kep, veći prinos u odnosu na kontrolu su imala stabla tretirana sa BA (tabela 5). Metamitron, primenjen samostalno i u kombinaciji sa NAA uticao je na statistički značajno povećanje krupnoće plodova. Primena sredstava za hemijsko proređivanje plodova nije uticala na oblik ploda, kao ni na čvrstoću i stepen obojenosti plodova. Kod sorte Red džonaprins, statistčki značajno manji prinos imala su stabla koja su tretirana metamitronom, kao i kombinacijama metamitron + NAA i karbaril + NAA. Krupnije plodove u odnosu na kontrolu imala su stabla prskana sa kombinacijama sredstava BA + NAA i metamitron + NAA. I kod sorte Red džonaprins primena bioregulatora nije uticala na indeks oblika ploda, čvrstoću i stepen obojenosti.

Tabela 4. Uticaj hemijskog proređivanja na prinos i kvalitet ploda kod sorti jabuke Gala rojal bjut i Zlatni delišes.
Influence of chemical thinning on yield and fruit quality in apple cultivars Gala Royal Beaut and Golden Delicious.

Tretman *Treatment*	Gala rojal bjut (*Gala Royal Beaut*)						Zlatni delišes Rajnders (*Golden Delicious Reinders*)				
	Prinos po stablu *Yield per tree* (kg)	Masa ploda *Fruit weight* (g)	Prečnik ploda *Fruit diameter* (mm)	Indeks oblika *Fruit shape index*	Čvrstoća mesa *Flesh firmness* (kg/cm^2)	Obojenost ploda *Fruit overcolor* (%)	Prinos po stablu *Yield per tree* (kg)	Masa ploda *Fruit weight* (g)	Prečnik ploda *Fruit diameter* (mm)	Indeks oblika *Fruit shape index*	Čvrstoća mesa *Flesh firmness* (kg/cm^2)
BA	7,12	162,4	68,7	0,94	8,0	53,0	12,41*	196,0	74,0*	0,96	7,3
NAA	5,38	167,3	69,5	0,94	7,3	78,5	9,21	206,9*	76,3*	0,97	7,6
Karbaril	6,72	164,6	69,8	0,95	7,9	73,5	9,24	173,2	72,1	0,94*	7,4
Metamitron	3,32*	170,0	69,4	0,96	7,3	74,5	6,44	274,1*	83,0*	0,97	7,6
BA + NAA	4,16*	183,6*	72,2*	0,94	7,4	72,0	7,07	246,8*	79,7*	0,97	6,9
Karbaril + NAA	6,57	176,1*	71,0*	0,96	8,2	65,0	7,01	200,4*	74,6*	0,98	7,4
Metam.+ NAA	3,98*	200,6*	75,4*	0,93	8,3	83,5*	5,03	262,2*	83,2*	0,95	7,6
Kontrola	7,45	151,5	66,7	0,95	7,7	66,0	7,19	166,4	70,1	1,00	7,5
LSD 0,05	2,86	18,90	3,20	0,05	0,61	12,70	3,19	30,20	3,60	0,03	0,57

* Zvezdice označavaju srednje vrednosti kod kojih su razlike u odnosu na kontrolu statistički značajne.

Kod sorte Gala rojal bjut, broj cvetnih pupoljaka naredne godine bio je zadovoljavajući kod svih tretmana, kao i u kontrolnoj varijanti (tabela 6). Optimalan broj plodova po cm^2 poprečnog preseka debla koja treba ostaviti u drugoj godini kod sorte Gala rojal bjut je 6-7. Ostavljanjem preko sedam plodova dobija se veći broj plodova, čiji je prečnik ispod 65 mm.

Kod sorte Zlatni delišes, dovoljan broj cvetnih pupoljaka za narednu godinu, imala su samo stabla koja su tretirana metamitronom i kombinacijom metamitron + NAA, odnosno stabla koja su imala oko četiri ploda po cm^2 površine poprečnog preseka debla. Unuk i sar. (2008) su utvrdili alternativnost kod sorte Zlatni delišes u trećoj godini, ako bi na stablima u drugoj godini imali preko 25 plodova, što se u našem ogledu nije javilo. Razlog tome leži u verovatno kvalitetnijem sadnom materijalu. Slična situacija je bila i kod sorte Red kep, s tim što je kod ove sorte, optimalan broj plodova po cm^2 površine porečnog preseka debla za dobro cvetanje naredne godine između 2 i 3. Taj broj su imala stabla koja su prskana sa metamitronom i kombinacijom metamitron + NAA.

Tabela 5. Uticaj hemijskog proređivanja na prinos i kvalitet ploda kod sorti jabuke Red kep i Red džonaprins.
Influence of chemical thinning on yield and fruit quality in apple cultivars Red cap and and Red Jonaprince.

Tretman *Treatment*	Red kep (*Red Cap*)						Red džonaprins (*Red Jonaprince*)					
	Prinos po stablu *Yield per tree* (kg)	Masa ploda *Fruit weight* (g)	Prečnik ploda *Fruit diameter* (mm)	Ind. oblika *Fruit shape index*	Čvrst. mesa *Flesh firmness* (kg/cm^2)	Obojen. ploda *Fruit overcolor* (%)	Prinos po stablu *Yield per tree* (kg)	Masa ploda *Fruit weight* (g)	Prečnik ploda *Fruit diameter* (mm)	Indeks oblika *Fruit shape index*	Čvrstoća mesa *Flesh firmness* (kg/cm^2)	Obojenost ploda *Fruit overcolor* (%)
BA	5,43*	177,9	71,4	0,95	7,6	96,0	7,63	220,0	78,2	0,90	7,6	51,0
NAA	3,92	188,0	72,6	0,96	7,8	97,0	7,09	270,9	85,4	0,86	6,9	62,0
Karbaril	4,50	187,6	73,1	0,97	7,5	96,0	8,53	213,2	78,6	0,86	6,8	61,5
Metamitron	3,06	258,9*	81,0*	0,97	7,4	95,0	4,12*	266,0	84,3	0,89	7,2	64,5
BA+ NAA	3,00	202,1	73,3	0,98	8,5	96,5	5,61	276,1*	83,8	0,92	7,1	62,0
Karbaril + NAA	3,51	200,3	73,8	0,94	7,2	92,5	4,78*	256,2	82,8	0,88	7,2	57,0
Metam.+ NAA	3,01	322,0*	88,7*	0,96	6,9	98,0	3,79*	303,4*	87,1*	0,90	7,2	57,0
Kontrola	4,17	179,8	69,9	0,95	7,6	94,0	6,84	233,1	80,8	0,88	7,0	58,0
LSD 0,05	1,17	34,50	5,20	0,06	0,71	4,20	1,87	35,60	4,70	0,06	0,56	8,90

* Zvezdice označavaju srednje vrednosti kod kojih su razlike u odnosu na kontrolu statistički značajne.

Tabela 6. Uticaj hemijskog proređivanja i opterećenja stabala na povratno cvetanje sorti jabuke.
Influence of chemical thinning and crop load on return bloom of apple cultivars.

Tretman *Treatment*	Gala rojal bjut (*Gala Royal Beaut*)		Zlatni delišes (*Golden Delicious*)		Red kep (*Red Cap*)		Red džonaprins (*Red Jonaprince*)	
	Broj plodova po cm^2 PPPD[1] *No. of fruits per TCSA*	Povratno cvetanje (broj CP[2]) *Return bloom (No. of FB)*	Broj plodova po cm^2 PPPD[1] *No. of fruits per TCSA*	Povratno cvetanje (broj CP[2]) *Return bloom (No. of FB)*	Broj plodova po cm^2 PPPD[1] *No. of fruits per TCSA*	Povratno cvetanje (broj CP[2]) *Return bloom (No. of FB)*	Broj plodova po cm^2 PPPD[1] *No. of fruits per TCSA*	Povratno cvetanje (broj CP[2]) *Return bloom (No. of FB)*
BA	7,2	50	12,1	4	6,8	2	7,3	15
NAA	5,4	70	8,5	10	4,6	6	5,6	30
Karbaril	6,8	50	10,3	2	5,4	3	8,6	10
Metamitron	3,3	80	4,4	70	2,6	50	3,2	80
BA + NAA	3,7	60	5,5	30	3,2	20	4,3	50
Karbaril + NAA	6,3	40	6,6	10	3,9	20	3,9	35
Metam. + NAA	3,3	80	3,7	80	2,1	80	2,6	80
Kontrola	8,1	50	8,3	10	5,2	2	6,2	10

[1]PPPD – površina poprečnog preseka debla / *TCSA – trunk cross-sectional area.*
[2]CP – cvetni pupoljci / *FB – flower buds.*

Kod sorte Red džonaprins samo stabla koja su imala 3-4 ploda po cm^2 površine poprečnog preseka debla su imala dovoljan broj cvetnih pupoljaka za narednu godinu, a to su bila stabla koja su prskana sa metamitronom, kao i kombinacijom preparata BA + NAA i metamitron + NAA.

Zaključak

Hemijsko proređivanje plodova ima značajan uticaj na zametanje plodova, prinos, povratno cvetanje i kvalitet ploda kod sorti jabuke Zlatni delišes Rajnders, Gala rojal bjut, Red kep i Red džonaprins. Najveći uticaj na smanjenje zametanja kod svih sorti imali su sledeći tretmani: metamitron samostalno i u kombinaciji sa NAA, NAA + BA, kao i karbaril + NAA. Primenom ovih hemijskih sredstava, došlo je do značajnog povećanja mase plodova u odnosu na kontrolu.

Kod sorti Zlatni delišes u Red kep, zbog povećanje mase ploda, prilikom tretiranja stabala gore pomenutim sredstvima, nije došlo do smanjenja prinosa u odnosu na kontrolu. Kod sorti Gala rojal Bjut i Red džonaprins, došlo je do značajnog smanjenja prinosa.

Sa aspekta povratnog cvetanja, odnosno diferenciranja cvetnih pupoljaka za narednu godinu, kod sorte Gala rojal bjut, hemijsko proređivanje plodova nije imalo veći značaj. Kod ove sorte sa opterećenjem od 6 do 7 plodova po cm^2 površine poprečnog preseka debla ostvaren je prinos preko 25 t/ha, uz zadržavanje kvaliteta plodova.

Kod sorti Zlatni delišes i Red kep, hemijsko proređivanje plodova ima veliki uticaj na povratno cvetanje. Kod ovih sorti, samo tretaman sa metamitronom samostalno i u kombinaciji sa NAA, obezbedio je dovoljan broj cvetnih pupoljaka i naredne godine. Optimalan broj plodova po cm^2 površine poprečnog preseka debla kod sorte Zlatni delišes u drugoj godini je 4-5, a kod sorte Red kep 2-3. Slična situacija je i kod sorte Red džonaprins, s tim da kod nje mogu da se ostave četiri ploda po cm^2 površine poprečnog preseka debla.

Zahvalnica

Ovaj rad je realizovan u okviru projekta III 43007 “Istraživanja klimatskih promena i njihovog uticaja na životnu sredinu: praćenje, adaptacija i ublažavanje”, koji finansira Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije.

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Influence of Chemical Thinning of Apple Cultivars on Yield and Fruit Quality

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This experiment was designed to investigate effects of chemical thinning on fruit set, yield, return bloom and fruit quality of apple cultivars ‘Golden Reinders’, ’Gala Royal Beaut’, ’Red Cap Deliciou" and ’Red Jonaprince’ in 2014. The orchard was established in spring 2013 with high-quality 2-year-old nursery trees that contained 7 or more lateral branches (except the cultivar ’Red Cap Delicious’). For chemical thinning the following chemicals were used: auxine naphthaleneacetic acid (NAA), cytokinin 6-benzyladenine (BA), insecticide carbaryl (‘Sevin’) and photosynthesis inhibitor metamitron (‘Brevis’) and their mix combinations.

The most intensive fruit thinning for all cultivars were obtained in treatments with metamitron used either alone or in combination with NAA, and in the combination BA + NAA. Due to the decrease in the number of fruits per tree, in these treatments was recorded the largest increase in fruit weight compared with the control. Application of bioregulators in two-year old orchard depending on the cultivar had a greater or lesser effect on apple bloom in the next spring. Effect of chemical thinning on flowering in the next spring was not significant in cultivars ‘Royal Gala Beaut’ and ‘Red Jonaprince’. In the cultivar ‘Golden Reinders’ number of fruits over 6 per cm^2 of trunk cross-sectional area (TCSA) resulted in absence of flowers, while in the cultivar Red Cap that number was 3 per cm^2 of TCSA.

Keywords: chemical thinning, apple cultivars, fruit set, yield, fruit size, return bloom.

Originalni naučni rad

UTICAJ PROHEKSADION-KALCIJUMA I ETEFONA NA BUJNOST SORTI TREŠNJE

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Izvod. Cilj ovog rada je bio ispitivanje uticaja kombinovane primene dva bioregulatora: proheksadion-kalcijuma i etefona na bujnost sorti trešnje. Ipitivanja su obavljena u proizvodnom zasadu trešnje u Grockoj na pet sorti: Burlat, Karmen, Sanberst, Kordija i Regina okalemljenih na podlozi Kolt. Tretman bioregulatorima je obavljen u proleće u dva navrata: početkom i krajem maja. Na kraju vegetacionog perioda izmereni su sledeći parametri: dužina i prečnik letorasta, broj nodusa, dužina internodija i površina lista. Svi ispitivani parametri bujnosti su, u manjoj ili većoj meri, imali manje vrednosti na stablima na kojima je obavljeno tretiranje bioregulatorima. Pored toga, bioregulatori su uticali na značajno povećanje broja formiranih majskih buketića kod svih ispitivanih sorti, osim kod sorte Burlat.

Ključne reči: trešnja, bujnost, bioregulatori, proheksadion-kalcijum, etefon.

Uvod

Srbija se po obimu proizvodnje trešnje nalazi na 18. mestu u svetu, a na 11. mestu u Evropi. Poslednjih godina porastao je izvoz svežih plodova trešnje, zbog čega raste i interesovanje za podizanje novih zasada. U Srbiji je većina zasada trešnje podignuta na generativnim podlogama (divljoj trešnji i magrivi) ili na vegetativnoj podlozi Kolt. Stabla trešnje na pomenutim podlogama karakteriše bujan porast i kasniji početak rodnosti.

U poslednje vreme podloga Kolt je ponovo aktuelna u Srbiji i trenutno je treća po zastupljenosti u našoj zemlji. Ova podloga je stvorena u Engleskoj (East Malling) kao međuvrsni hibrid (*Prunus avium* × *Prunus pseudocerasus*) i u proizvodnji je od 1977. godine. Lako se vegetativno razmnožava nagrtanjem. Milatović (2015) navodi da je bujnost okalemljenih sorti na podlozi Kolt u prvim godinama slična kao na sejancu divlje trešnje, dok je kod starijih stabala bujnost manja za 10-30%. Mišić (1984) navodi da je podloga Kolt dobre kompatibilnosti sa gotovo svim sortama trešnje. Cerović i saradnici (2015) navode da je Kolt za 5% manje bujnosti od divlje trešnje i magrive.

Utvrđeno je da retardanti rasta daminozid i paklobutrazol inhibiraju biosintezu giberelina i redukuju vegetativni rast kod trešnje (Thomas, 1982; Facteau and Chesnut, 1991). Međutim, ovi preparati nisu pogodni za komercijalnu upotrebu zbog vrlo spore razgradnje i potencijalne toksičnosti.

Proheksadion – kalcijum pod trgovačkim nazivom “Regalis” se koristi već duže vreme za smanjenje porasta letorasta stabala jabuke. Poluživot ovog preparata u biljkama je samo 14 dana, nakon čega se razgrađuje. Više autora navodi da ovaj bioregulator inhibira biosintezu aktivne giberelinske kiseline (Evans et al., 1999; Rademacher, 2000) i time utiče na redukovani porast mladara. Kod trešnje su postignuti dobri rezultati u smanjenju rasta mladara prilikom primene proheksadion – kalcijuma u koncentraciji 150-300 mg/l nakon cvetanja (Manriquez et al., 2005). Featherstone (2001) navodi da kombinacija preparata Apogee (proheksadion-kalcijum) i Etrel (etefon) može da posluži za inhibiciju porasta vršnih grana na trešnji. Pri kombinovanoj primeni ovih preparata (dva tretmana u razmaku od tri nedelje), pored smanjenog porasta mladara, dobijena je i značajno veća gustina cvetnih pupoljaka u narednoj godini (Elfving et al., 2004).

Cilj rada je bio ispitivanje uticaja proheksadion – kalcijuma i etefona na smanjenje bujnosti i formiranje majskih buketića kod pet sorti trešnje. Dobijeni rezultati bi mogli poslužiti za preporuku tretiranja mladih stabala trešnje na bujnim podlogama u komercijalnoj proizvodnji.

Materijal i metode

Istraživanja su obavljena tokom 2016. godine u komercijalnom zasadu trešnje na površini od 2 ha. Zasad se nalazi u opštini Grocka i podignut je 2013. godine na rastojanju 5 × 3 m. Ogled je postavljen na pet sorti: Burlat, Karmen, Sanberst, Kordija i Regina. Sva stabla su okalemljena na vegetativnoj podlozi Kolt. Stabla su prvi rod donela u 2016. godini. Zbog izražene bujnosti i malog broja cvetnih pupoljka obavljen je tretman sa bioregulatorima i to u dva navrata. Cvetanje ispitivanih sorti je bilo od 5. do 15. aprila. Prvi tretman je obavljen 5. maja kada su letorasti na vrhu stabala imali dužinu 8-10 cm. Za tretiranje je korišćeno 250 g Regalisa (proheksadion – kalcijum) i 175 g Etrela (etefon) na 1.000 litara vode. Na površinu od 1 ha utrošeno je 1.000 litara rastvora. U svakom redu su preskočena prva tri stabla (9 stabala po sorti) koja su poslužila kao kontrola. Drugi tretman je obavljen tri nedelje kasnije i bio je identičan sa prvim tretmanom. Vremenski uslovi u danima tretiranja su bili vrlo povoljni. Temperature vazduha su bile 18 i 20°C, bez padavina i uz minimalnu brzinu vetra.

Na kraju vegetacionog perioda (oktobar) obavljena su merenja sledećih parametara: dužina letorasta, debljina letorasta, broj nodusa po letorastu, površina lista i broj majskih buketića po stablu. Letorasti su uzimani sa vrha stabla. Od svake sorte je uzeto po 20 letorasta. Računskim putem je dobijena prosečna dužina internodija. Majski buketići su prebrojavani na celom stablu.

Ogled je postavljen po potpuno slučajnom blok sistemu gde je svaka sorta bila zastupljena sa tri ponavljanja, a u okviru jednog ponavljanja su praćena po tri stabla. Kod svake sorte ispitivanja su obavljena na devet stabala sa tretmanom (primenom bioregulatora) i na devet stabala bez tretmana (kontrola). Rezultati su statistički obrađeni za svaku sortu posebno. Značajnost razlika između srednjih vrednosti ispitivanih parametara je determinisana korišćenjem LSD testa za verovatnoću 0,05.

Rezultati i diskusija

U tabeli 1 su prikazane prosečne vrednosti ispitivanih parametara kod pet sorti trešnje na stablima koja su tretirana bioregulatorima, kao i na stablima bez tretmana (kontrola).

Tabela 1. Prosečne vrednosti ispitivanih parametara kod pet sorti trešnje.
Mean values of studied parameters in five sweet cherry cultivars.

Sorte/ Tretmani *Cultivars/ Treatments*	Dužina letorasta *Length of shoots* (cm)	Prečnik letorasta *Diameter of shoots* (mm)	Broj nodusa *Number of nodes*	Dužina internodija *Length of internodes* (cm)	Površina lista *Leaf area* (cm^2)	Broj majskih buketića *Number of spurs*
Burlat - kontrola	77,8	11,4	33,0	2,35	64,9	24,3
Burlat - tretman	58,9	9,46	30,0	1,96	60,5	26,0
$LSD_{0,05}$	8,95*	1,34*	2,27*	0,22*	1,85*	4,90
Karmen - kontrola	74,5	11,71	31,6	2,34	72,9	130,6
Karmen - tretman	48,7	10,27	20,0	2,43	67,3	145,0
$LSD_{0,05}$	25,46*	2,02	10,56*	0,12	2,89*	10,68*
Sanberst - kontrola	90.5	12,14	33,7	2,68	65,1	84,3
Sanberst - tretman	64,9	9,98	25,0	2,60	60,7	146,6
$LSD_{0,05}$	16,91*	2,78	6,49*	0,40	1,69*	26,0*
Kordija - kontrola	105,0	11,04	32,7	3,21	74,3	98,3
Kordija - tretman	69,7	11,00	27,3	2,55	66,0	135,0
$LSD_{0,05}$	14,7*	1,49	3,47*	0,43*	2,24*	21,19*
Regina - kontrola	83,3	11,24	25,3	3,33	77,7	128,0
Regina - tretman	56,2	9,86	20,3	2,76	67,6	159,7
$LSD_{0,05}$	11,95*	2,11	6,55	0,51*	2,55*	16,78*

Najveća prosečna dužina vršnih letorasta (105,0 cm) je izmerena kod sorte Kordija na kontrolnim stablima. Najmanju dužinu letorasta su imala stabla sorte Karmen na tretiranim stablima (48,7 cm). Dužina vršnih letorasta trešnje je jedan od značajnih pokazatelja bujnosti. Kod svih pet ispitivanih sorti razlika prosečne dužine letorasta na tretiranim i netretranim stablima je bila statistički značajna. Smanjenje dužine letorasta kod tretiranih stabala u odnosu na kontrolu je iznosilo od 24% kod sorte Burlat do 35% kod sorte Karmen. Manji porast vršnih letorasta ispitivanih stabala trešnje je rezultat dejstva upotrebljenih preparata. Elfving et al. (2004) su ispitivali dužinu terminalnih letorasta kod sorti Kordija, Bing i Regina sa identičnim tretmanom i takođe su dobili značajno manji porast. Cline (2008) je sa dvostrukim tretmanom sa proheksadion – kalcijumom takođe dobio umanjeni rast letorasta trešnje za oko 30%.

Prosečne vrednosti prečnika vršnih letorasta su kod svih ispitivanih sorti bile nešto manje na tretiranim stablima. Međutim, ove razlike nisu bile statistički značajne, osim kod sorte Burlat.

Prosečan broj nodusa na vršnim letorastima je bio manji na tretiranim stablima u poređenju sa kontrolnim stablima. Razlike prosečnih vrednosti su bile statistički značajne kod svih ispitivanih sorti, osim kod sorte Regina.

Prosečna dužina internodija na vršnim letorastima je kod svih ispitivanih sorti bila manja na stablima tretiranim retardantima, osim kod sorte Karmen. Razlike su bile statistički značajne kod sorti Burlat, Kordija i Regina. Manji broj nodusa i dužina internodija se takođe mogu tumačiti kao rezultat delovanja upotrebljenih preparata.

Najmanja prosečna površina lista je izmerena na tretiranim stablima sorte Burlat (60,5 cm^2), dok su najveću površinu imali listovi sorte Regina na netretiranim stablima (77,7 cm^2). Sve ispitivane sorte su imale statistički značajno manju površinu lista na stablima koja su tretirana bioregulatorima. Dva tretmana proheksadion - kalcijumom i etefonom su uticali na smanjenje površine lista kod ispitivanih sorti trešnje za 7 do 13%.

Najmanji broj majskih buketića po stablu je utvrđen kod netretiranih stabala sorte Burlat (24,3) a najveći broj su imala tretirana stabla sorte Regina (159,7). Sve ispitivane sorte su imale veći broj majskih buketića na stablima koja su tretirana bioregulatorima. Razlike prosečnih vrednosti broja majskih buketića tretiranih i kontrolnih stabala su bile statistički značajne kod svih sorti, osim kod sorte Burlat. Povećanje broja majskih buketića je iznosilo od 12% kod sorte Karmen do 74% kod sorte Sanberst. Dobijeni rezultat je nastao pod uticajem primene bioregulatora. Kod sorte Burlat tretiranje nije uticalo na povećanje broja majskih buketića zbog poznate genetske predispozicije ove sorte ka kasnom ulasku u rodnost. Elfving et al. (2004) su sa istim tretmanom takođe dobili povećanje broja cvetnih pupoljka na tri ispitivane sorte trešnje.

Zaključak

Na osnovu rezultata dobijenih ispitivanjem uticaja dvokratnog tretiranja stabala pet sorti trešnje kombinacijom proheksadion – kalcijuma i etefona mogu se doneti sledeći zaključci:

- Sve ispitivane sorte trešnje su imale značajno umanjen porast vršnih letrorasta (za 24-35%).

- Broj nodusa i dužina internodija na vršnim letorastima su bili značajno manji kod većine ispitivanih sorti.

- Sve ispitivane sorte su imale značajno manju površinu lista na vršnim letorastima. Ovaj rezultat se može smatrati nepovoljnim efektom u slučaju da se radi o zasadima koji već rađaju, jer se smanjenje površine lista može negativno odraziti na prinos i kvalitet ploda.

- Sve ispitivane sorte su imale, u manjoj ili većoj meri, bolju diferencijaciju cvetnih pupoljaka pod uticajem primenjenih bioregulatora, što se ogledalo u povećanju broja formiranih majskih buketića (za 12-74%).

Na osnovu dobijenih rezultata, može se zaključiti da se kombinovana primena proheksadion-kalcijuma i etefona može preporučiti za upotrebu u mladim komercijalnim zasadima trešnje na bujnim podlogama za smanjenje bujnosti i podsticanje ranije diferencijacije cvetnih pupoljaka.

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Influence of Prohexadione-Calcium and Ethephon on Vigor of Sweet Cherry Cultivars

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Summary

In Serbia, in the majority of sweet cherry orchards, vigorous rootstocks (Mazzard and Mahaleb seedlings and clonal rootstock ‘Colt’) are used. Cherry trees grafted on these rootstocks are characterized by vigorous growth and the subsequent late coming into bearing. The aim of this study was to examine the effect of the combined use of two bioregulators: Prohexadione-calcium and Ethephon on vigor of sweet cherry cultivars. Studies were carried out in a cherry orchard in Grocka (near the Belgrade) on five cultivars: ‘Bigarreau Hatif Burlat’, ‘Sunburst’, ‘Carmen’, ‘Kordia’ and ‘Regina’ grafted on the rootstock ‘Colt’. There were two treatments with Prohexadione-calcium (250 mg/l) and Ethephon (175 mg/l). The first treatment was done when the shoots were 8-10 cm long, and the second one three weeks later. At the end of the growing season were conducted measurements of the following parameters: length of shoots, diameter of shoots, number of nodes per shoot, leaf area, and the number of spurs per tree. All parameters of vigor had less values on the trees treated with bioregulators. Length of the terminal shoots on treated trees was lower by 24-35% comparing to control. In addition, bioregulators influenced significant increase in the number of spurs (by 12-74%) in all tested cultivars, except for the cultivar ‘Burlat’.

Key words: sweet cherry, vigor, bioregulators, prohexadione-calcium, ethephon.

Originalni naučni rad

UTICAJ 1-METILCIKLOPROPENA NA KVALITET PLODOVA JABUKE SORTE „GRANNY SMITH“ U ZAVISNOSTI OD PRIMENJENE KONCENTRACIJE I USLOVA ČUVANJA

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Izvod. U radu su prikazani rezultati ispitivanja delovanja 1-metilciklopropena (1-methylcyclopropene, 1-MCP) na kvalitet plodova jabuke sorte „Granny Smith“. 1-MCP je inhibitor delovanja etilena koji se veže za receptore etilena i na taj način usporava sazrevanje plodova i produžava njihovo čuvanje. 1-MCP je primenjen u periodu od 5 dana nakon berbe u koncentracijama od 0, 500, 1000 i 2000 ppb i to sa i bez prisustva egzogenog etilena poreklom iz druge zrele jabuke. Nakon tretmana plodovi su smešteni u hladnjaču sa kontrolisanom atmosferom u dve komore sa različitim sastavom gasova. Analize plodova su izvedene neposredno nakon iskladištenja, ali i nakon dodatnog čuvanja u komori sa normalnom atmosferom, kao i nakon čuvanja na sobnoj temperaturi. Rezultati su pokazali da 1-metilciklopropen može u značajnoj meri da pomogne očuvanju kvaliteta jabuke tokom skladištenja u hladnjačama. Nevezano za primenjenu koncentraciju, 1-MCP značajno utiče na očuvanje čvrstine ploda, čak i nakon iskladištenja odnosno čuvanja plodova na sobnoj temperaturi, a pokazalo se i da sadržaj ukupnih kiselina u tretiranim plodovima sporije opada u odnosu na netretirane plodove. Nije bilo uticaja tretmana na sadržaj rastvorljivih suvih materija. Sve ispitivane koncentracije 1-MCP-a su efikasno suzbile pojavu posmeđivanja pokožice zelenih plodova (skald) samo u uslovima kada je tretman vršen u komori bez prisustva plodova jabuke drugih sorti. U tretmanu sa prisustvom egzogenog etilena, 1-MCP nije sprečio pojavu skalda. Koncentracija od 500 ppb nije dala zadovoljavajuće rezultate kod svih ispitivanih parametara, te je preporučljivo da se koristi koncentracija od 1000 ppb. Koncentracija od 2000 ppb je dala iste rezultate kao i 1000 ppb, pa stoga nema opravdanja za njenu primenu.

Ključne reči: 1-MCP, ULO, NA, čvrstina, skald.

Uvod

Proces zrenja plodova jabuke je u velikoj meri kontrolisan etilenom, biljnim hormonom koji se proizvodi u većini biljnih tkiva. Etilen je gas koji deluje i kad je prisutan u tragovima, stimulišući i regulišući različite procese tokom života biljaka, kao što su: zrenje plodova, otvaranje cvetova, opadanje listova. Njegova produkcija je obično mala, ali kad se poveća izaziva važne fiziološke promene, uključujući zrenje klimakteričnih plodova (Vendrell et al., 2001). Budući da se produkcija etilena odvija i tokom čuvanja plodova, u svetu se već dugo radi na pronalaženju načina inhibicije njegovog stvaranja i delovanja.

Jedan od inhibitora delovanja etilena je 1-metilciklopropen koji se veže za receptore etilena (Sisler i Serek, 1997) i na taj način usporava sazrevanje plodova i produžava njihovo čuvanje (Fan i Mattheis, 1999; Dal Cin et al., 2008; Fawbush et al., 2009). 1-MCP je aktivna materija preparata SmartFresh^{TM} koji je registrovan za upotrebu u većini evropskih zemalja, kao i u Srbiji. 1-MCP je skoro idealan sastojak za tretiranje biljnog materijala osetljivog na etilen, jer se može primeniti kao gas, aktivan je u veoma niskim koncentracijama, ima dugotrajno dejstvo, nije toksičan i nema miris (Sisler, 2006). Tretiranje plodova klimakteričnog voća, kao što su jabuke i kruške, 1-MCP-om usporava se proces sazrevanja. 1-MCP blokira efekte i endogenog i egzogenog etilena (Rupasinghe et al., 2000). Posebno je značajna činjenica da 1-MCP smanjuje kalo pojedinačnih plodova tokom čuvanja (Akbudak et al., 2009).

Jabuka je voćna vrsta kod koje 1-MCP daje najbolje rezultate i ima standardnu primenu. Daje odlične rezultate na plodovima čuvanim i u normalnoj (Coureau et al., 2005) i u kontrolisanoj atmosferi (DeLong et al., 2004; Magazin et al., 2013;). Plodovi su čvršći, sočniji, period čuvanja se produžava i duže se zadržava zelena osnovna boja pokožice. Pored toga, sprečava pojavu skalda kod osetljivih sorti kao što je „Granny Smith“ (Magazin et al., 2010). Međutim, efikasnost preparata zavisi od pridržavanja uputstvima za primenu. Pored toga, na nekim sortama primena nije preporučljiva jer dovodi do izraženije pojave pojedinih fizioloških oboljenja (DeEll et al., 2003).

Materijal i metode

Ogled je postavljen u toku 2010. godine na sorti jabuke „Granny Smith“. Preparat Smart Fresh 0.14% Technology (a.m. 1-methylcyclopropene) je primenjen u periodu od 5 dana nakon berbe u koncentracijama od 0, 500, 1000 (registrovana konc.) i 2000 ppb aktivne materije 1-MCP na uzorcima od 2 x 100 plodova podeljenih u 4 ponavljanja. Tretman je trajao 24 časa, a nakon toga plodovi (4 x 25 plodova iz svakog tretmana) su smešteni na čuvanje u komore hladnjače u uslove opisane u tabeli 1. U istoj tabeli su dati i termini analize plodova. Analize plodova su izvedene prema rasporedu datom u istoj tabeli, a obuhvatale su sledeće karakteristike: čvrstina plodova ručnim penetrometrom FT 327 (Winopal Forshchungsbedarf GmbH, Ahnsbeck, Nemačka) sa ubodnom iglom prečnika 11 mm, sadržaj rastvorljive suve materije ručnim refraktrometrom RHB-32ATC (Xin instruments, Kina), sadržaj ukupnih kiselina (titracijom sa 0,1 N NaOH), prisustvo posmeđivanja pokožice zelenih plodova (skald) je određeno prebrojavanjem plodova sa simptomima, a jačina pojave je određena subjektivno i izražena je u procentima (%) od ukupne površine ploda.

Eksperimentalni podaci su obrađeni uz pomoć softverskog paketa STATISTICA (verzija 10) primenom analiza varijanse (ANOVA). Značajnost razlika između tretmana određena je LSD testom sa nivoom značajnosti od 0,05%.

Tabela 1. Osnovni podaci o ogledu
The basic data of the experiment

Komora *Chamber*	ULO 1	ULO 2
Režim atmosfere i temperature *Atmosphere and temperature conditions*	0,8% O_2, 0,8%CO_2, 1°C	1,5% O_2, 2,5%CO_2, 1,5°C
Napomene *Remarks*	Komora bez druge jabuke *Chamber without other apples*	Tretiranje obavljeno u komori u prisustvu zrele jabuke drugih sorti *Treatment done in chamber with resence of ripe apples of other cultivars*
Vreme analize plodova (nakon) Analysis time (after)	1. 155 dana čuvanja u ULO *155 days in ULO storage* 2. 155 dana čuvanja u ULO + 7 dana na 20°C *155 days in ULO storage* *+ 7 days at 20°C* 3. 155 dana čuvanja u ULO + 30 dana u NA *155 days in ULO storage* *+ 30 days in NA*[1] *storage* 4. 155 dana čuvanja u ULO + 30 dana u NA + 7 dana na 20°C *155 days in ULO storage* *+ 30 days in NA storage* *+ 7 days at 20°C*	1. 180 dana čuvanja u ULO *180 days in ULO storage* 2. 180 dana čuvanja u ULO + 7 dana na 20°C *180 days in ULO storage* *+ 7 days at 20°C* 3. 180 dana čuvanja u ULO + 30 dana u NA uslovima *180 days in ULO storage* *+ 30 days in NA storage* 4. 180 dana čuvanja u ULO + 30 dana u NA + 7 dana na 20°C *180 days in ULO storage* *+ 30 days in NA storage* *+ 7 days at 20°C*

[1] Normalna atmosfera / *Normal atmosphere*

Rezultati i diskusija

Čvrstina je jedan od dominantnih faktora koja opredeljuje potrošače za kupovinu plodova jabuke (Harker et al., 2002). Iz rezultata prikazanih u tabelama 2 i 3. se vidi da je efekat 1-MCP-a vidljiv već tokom skladištenja u ULO uslovima. Nevezano od uslova u komori, netretirani plodovi su imali znatno manju čvrstinu neposredno nakon iskladištenja iz ULO uslova, ali i nakon dodatnog čuvanja u NA uslovima. Nisu primećene značajne razlike u čvrstini plodova poredeći dve komore, što govori da prisustvo etilena nije uticalo na čvrstinu plodova tokom čuvanja.

Tabela 2. Kvalitet plodova sorte „Granny Smith“ u zavisnosti od koncentracije 1-MCP-a i dužine čuvanja u kontrolisanim uslovima (ULO 1).
The quality of the fruits of cultivar 'Granny Smith' depending on the concentration of 1-MCP and the duration of storage under controlled conditions (ULO 1)

Dužina čuvanja plodova *Storage lenght*	Tretman *Treatment*	Čvrstina plodova *Fruit firmness* (kg/cm^2)	Sadržaj rastv. suve materije *Soluble solids content* (%)	Sadržaj ukupnih kiselina *Titratable acidity* (%)	Plodovi sa simptomima skalda *No. of fruits with scald symptoms* (%)	Jačina pojave skalda *Scald intensity* (%)
Berba / *Harvest*	/	8,56abcd	11,97	1,06a	/	/
155 dana u ULO *155 days in ULO*	Kontrola	7,91g	12,64	0,83bcde	0	0,0b
	500 ppb	8,70a	12,76	0,86bc	0	0,0b
	1000 ppb	8,62ab	12,94	0,90b	0	0,0b
	2000 ppb	8,66ab	12,50	0,83bcde	0	0,0b
155 dana u ULO + 7 dana na 20°C *155 days in ULO + 7 days at 20°C*	Kontrola	7,89g	13,14	0,73g	0	0,0b
	500 ppb	8,42bcd	13,22	0,82cde	0	0,0b
	1000 ppb	8,54abc	12,98	0,85bcd	0	0,0b
	2000 ppb	8,60abc	13,26	0,80cdef	0	0,0b
155 dana u ULO + 30 dana u NA *155 days in ULO + 30 days in NA*	Kontrola	8,22def	14,08	0,84bcde	0	0,0b
	500 ppb	8,33cde	13,48	0,86bc	0	0,0b
	1000 ppb	8,40bcd	13,66	0,81cdef	0	0,0b
	2000 ppb	8,59abc	12,86	0,82cde	0	0,0b
155 dana u ULO + 30 dana u NA + 7 dana na 20°C *155 days in ULO + 30 days in NA + 7 days at 20°C*	Kontrola	7,33h	13,94	0,62h	53	14,0a
	500 ppb	8,10efg	13,80	0,77efg	0	0,0b
	1000 ppb	8,02fg	13,78	0,78defg	0	0,0b
	2000 ppb	7,96fg	13,62	0,74fg	0	0,0b

Najveće razlike između tretiranih i netretiranih plodova su ispoljene nakon dodatnog čuvanja plodova na sobnoj temperaturi što su utvrdili i drugi istraživači (Rupasinghe et al., 2000; Zanella, 2003; Coureau et al., 2005; Akbudak et al., 2009; Magazin et al., 2013). Čvrstina netretiranih plodova je bila značajno niža od čvrstine tretiranih plodova bez obzira na primenjenu koncentraciju 1-MCP, s tim što je koncentracija od 500 ppb pokazala lošiju efikasnost u komori ULO 2 (tabela 3).

Sadržaj rastvorljivih suvih materija (RSM) se statistički nije značajno razlikovao bez obzira na tretmane i dužinu čuvanja, odnosno vreme analize plodova (tabele 2 i 3) što je potvrđeno i u drugim radovima (Rupasinghe et al., 2000; Zanella, 2003; Akbudak et al., 2009).

Tretman 1-MCP-om je imao značajan uticaj i na sadržaj ukupnih kiselina tokom čuvanja što nije uvek slučaj (Johnson, 2003; Zanella, 2003). U našem ogledu se to posebno pokazalo nakon iskladištenja, odnosno čuvanja plodova 7 dana na sobnoj temperaturi (tabele 2 i 3). Koncentracija od 1000 ppb 1-MCP je pokazala najbolji efekat na očuvanje sadržaja kiselina nakon izlaganja plodova sobnoj temperaturi u obe komore.

Tabela 3. Kvalitet plodova sorte „Granny Smith“ u zavisnosti od koncentracije 1-MCP-a i dužine čuvanja u kontrolisanim uslovima (ULO 2).
The quality of the fruits of cultivar 'Granny Smith' depending on the concentration of 1-MCP and the duration of storage under controlled conditions (ULO2).

Dužina čuvanja plodova *Storage lenght*	Tretman *Treatment*	Čvrstina plodova *Fruit firmness* (kg/cm^2)	Sadržaj rastv. suve materije *Soluble solids content* (%)	Sadržaj ukupnih kiselina *Titratable acidity* (%)	Plodovi sa simptomima skalda *No. of fruits with scald symptoms* (%)	Jačina pojave skalda *Scald intensity* (%)
Berba / *Harvest*	/	8,49ab	11,40	0,99a	/	/
155 dana u ULO *155 days in ULO*	Kontrola	8,01de	13,08	0,71de	46	5,9gh
	500 ppb	8,15cd	12,78	0,72d	30	3,8h
	1000 ppb	8,41ab	13,16	0,73cd	61	12,1fg
	2000 ppb	8,55a	12,94	0,71de	44	6,3gh
155 dana u ULO + 7 dana na 20°C *155 days in ULO + 7 days at 20°C*	Kontrola	8,14cd	12,88	0,58j	100	64,6b
	500 ppb	8,16cd	13,28	0,65fghi	99	62,5b
	1000 ppb	8,51a	12,82	0,68ef	99	72,6a
	2000 ppb	8,57a	13,38	0,65fgh	99	51,8d
155 dana u ULO + 30 dana u NA *155 days in ULO + 30 days in NA*	Kontrola	8,04de	13,00	0,62hij	99	11,1fg
	500 ppb	8,14cd	12,18	0,65fghi	35	20,3e
	1000 ppb	8,55a	12,34	0,77b	30	16,5ef
	2000 ppb	8,61a	12,78	0,76bc	55	8,5gh
155 dana u ULO + 30 dana u NA + 7 dana na 20°C *155 days in ULO + 30 days in NA + 7 days at 20°C*	Kontrola	7,38f	12,76	0,63ghi	100	55,9cd
	500 ppb	7,90e	12,70	0,62ij	100	72,8a
	1000 ppb	8,25bc	12,36	0,67fg	100	60,9bc
	2000 ppb	8,59a	13,34	0,71de	97	60,0bc

Rezultati prikazani u tabeli 2. pokazuju da 1-MCP u potpunosti suzbija pojavu skalda na plodovima ispitivane sorte u slučaju pravilne primene. Simptomi skalda su se javili samo na netretiranim plodovima koji su se čuvali u ULO, NA i sobnim uslovima, po redosledu. Slično su utvrdili i drugi istraživači na plodovima čuvanim u ULO (Magazin et al., 2013) i na NA (Fan et al., 1999) uslovima, a pogotovo nakon izlaganja sobnoj temperaturi (Akbudak et al., 2009). Međutim, ukoliko se suprotno preporukama proizvođača, 1-MCP primeni u prisustvu etilena, odnosno zrele jabuke kakav je slučaj u komori ULO 2 (tabela 3), ne može da se suzbije pojava skalda (Watkins, 2008) ni u jednoj od primenjenih koncentracija. Iako postoje izvesne statističke razlike u intenzitetu i broju plodova sa skaldom, treba istaći da je skald fiziološko oboljenje koje utiče na izgled plodova te je prag tolerancije nizak. Prema Gvozdenović et al. (2005), simptomi skalda na plodovima ne bi smeli uopšte da postoje.

Zaključak

1-metilciklopropen može u značajnoj meri da pomogne očuvanju kvaliteta jabuke tokom skladištenja u hladnjačama. Efekat je posebno izražen na čvrstinu plodova, kao i na sadržaj ukupnih kiselina. 1-MCP može uspešno da suzbije pojavu skalda kod sorte „Granny Smith“, ali je efikasnost zagarantovana samo ako se tretman vrši bez prisustva etilena u komori, u skladu sa preporukama proizvođača. Koncentracije 1-MCP-a od 1000 i 2000 ppb su dale najbolje rezultate, te je registrovana koncentracija od 1000 ppb preporučljiva za primenu, dok nema opravdanja za primenu koncentracije od 2000 ppb.

Zahvalnica

Prezentovani rezultati su deo istraživanja u okviru projekata: “Organska poljoprivreda: Unapređenje proizvodnje primenom đubriva, biopreparata i bioloških mera“ (TR 31027).

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The Influence of 1-Methylcyclopropene on Fruit Quality of “Granny Smith” Apple Cultivar Depending on Applied Concentration and Storage Conditions

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Summary

The paper presents the results of 1-methylcyclopropene (1-methylcyclopropene, 1-MCP) influence on fruit quality of “Granny Smith” apple cultivar. 1-MCP is an inhibitor of ethylene action which binds to the receptors of ethylene and thus delays the maturity of fruit, and prolongs their storage. 1-MCP is applied in a period of 5 days after harvest at concentrations of 0, 500, 1000 and 2000 ppb, each with and without the presence of exogenous ethylene from other ripe apples. After treatment, the fruits were stored in cold storage with controlled atmosphere (CA) in two separate chambers with different composition of the gases. Fruits analyses were made immediately after CA storage, after additional storage in normal atmosphere, and after room temperature shelf life. The results showed that 1-methylcyclopropene can significantly help preserve the quality of apple during cold storage. Irrespective of the applied concentration 1-MCP significantly affects retention of fruit firmness even during shelf life, and also affects the total acids (TA) content in the treated fruits by slowing down drop of TA compared to untreated fruits. There was no treatment effect on total soluble solids content. All tested concentrations of 1-MCP effectively suppress the occurrence of superficial scald in circumstances where the treatment is carried out in the chamber without the presence of other apple cultivars. In the case where the treatment is done in presence of exogenous ethylene 1-MCP has not prevented scald occurrence. A concentration of 500 ppb has not yielded satisfactory results with all investigated parameters, while a concentration of 1000 ppb is recommended to be used. The concentration of 2000 ppb gives the same results as 1000 ppb and there is no justification for its application.

Key words: 1-MCP, ULO, NA, firmness, superficial scald.

Originalni naučni rad

UTICAJ 1-METILCIKLOPROPENA (1-MCP) NA ČUVANJE PLODOVA KRUŠKE SORTE 'VILIJAMOVKA'

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Izvod. Cilj ovog rada bio je ispitati uticaj tretmana 1-metilciklopropenom (1-MCP) na čuvanje i promjenu kvaliteta plodova kruške sorte 'Vilijamovka'. Plodovi kruške tretirani su sa 1-MCP (Smartfresh^{TM}; 0,14% MCP) koncentracije625 ppb tokom 24 sata, a zatimuskladišteni tokom dva mjeseca na temperaturi od 4°C i uslovima od 90% relativne vlage zraka (NA hladnjača). Neki parametri kvaliteta, kao što su čvrstoća mesa ploda, sadržaj ukupno rastvorljive suhe tvari, sadržaj titracijskih kiselina i boja pokožice ploda (određena kolorimetrijski) su mjereni prije *postharvest* treatmana 1-MCP-om, kao i nakon skladištenja u trajanju od 60 dana. Dobijeni rezultati su pokazali da je tretman 1-MCP bio učinkovit na stepen omekšavanja plodova, povećanje sadržaja ukupno rastvorljive suhe tvari i smanjenje sadržaja titracijskih kiselina u plodu. 1-MCP nije imao značajan uticaj na promjenu boje pokožice ploda. Na osnovu dobijenih rezultata ovog istraživanja 1-MCP se može preporučiti kao potencijalno dobro sredstvo za odlaganje dozrijevanja i promjena u kvalitetu plodova kruške tokom 60 dana čuvanja u hladnjači.

Ključne riječi: 1-metilciklopropen (1-MCP), skladištenje, kruška, kvalitet ploda, SmartFresh.

Uvod

Po proizvodnji u svijetu kruška zauzima drugo mjesto među listopadnim voćkama, odmah iza jabuke. Prema podacima FAOSTAT (2016) prosječna proizvodnja kruške u svijetu u 2014. godini iznosila je 25,7 miliona t.Glavni proizvođač je Kina, a za njom slijede SAD, Italija, Argentina i Španija. Prema podacima zavoda za statistiku BiH godišnja proizvodnja kruške u Bosni i Hercegovini za 2015. godinu iznosila je 27400 t. Na prostoru Bosne i Hercegovine najzastupljeniji je sljedeći sortiment krušaka: 'Vilijamovka', 'Kaluđerka', 'Butira', 'Santa Marija', 'Junsko zlato', 'Šampionka', 'General Leklerk', 'Kleržo', 'Pakams trijumf' i dr.

Rezultati analize vanjskotrgovinske razmjene za sektor voća i povrća u BiH za period 2011-2015. ukazuju da svježi plodovi kruške spadaju u top tri izvozna proizvoda, prema količini i vrijednosti izvoza (Begović, 2016). Dakle, Bosna i Hercegovina izveze oko 5651 tkrušaka u svježem stanju, a najveći izvoz se ostvaruje prema Rusiji (96%, ukupne vrijednosti 10,353,638 KM).

Proizvođači voća u Bosni i Hercegovini uglavnom ne raspolažu adekvatnim kapacitetima za skladištenje (ULO, ULE, DA hladnjače). Najzastupljeniji je NA tip hladnjača ili improvizovana skladišta u vidu preuređenih podrumskih prostorija. Zbog toga su prinuđeni da veći dio proizvoda prodaju neposredno nakon berbe, kako bi izbjegli gubitke u njihovom kvalitetu. Razumljivo je da je cijena plodova u tom periodu dosta niska, usljed velike ponude na tržištu. Ubrzo zatim otvara se mogućnost uvoza velikih količina voća budući da se domaće zalihe potroše, što se događa uglavnom tokom zimskih mjeseci i dalje tokom naredne godine. Na ovaj način u Bosni i Hercegovini se godišnje uvoze značajne količine plodova kruške (7500 t u 2015. godini). Razlog tome je upravo činjenica da voćarski razvijene zemlje posjeduju odgovarajuće skladišne kapacitete u kojima postoji mogućnost dugotrajnijeg čuvanja plodova i plasiranja na tržište onda kada se za to ukaže potreba.

Ipak, da bi se osiguralo kvalitetno skladištenje plodova kruške,neophodno je proizvesti plodove visokog kvatiteta, obrati ih u optimalnom vremenu i uskladištiti u odgovarajućim uslovima.Jedan od važnih faktora koji utiče na proces čuvanja voća je gasoviti fitohormon etilen, koji u malim koncentracijama dovodi do aktiviranja procesa usmjerenih ka senescenciji (starenju) plodova, što u konačnici dovodi do njihovog propadanja. Zbog toga je kontrola etilena neposredno nakon berbe i tokom skladištenja plodova voćaka od presudnog značaja za očuvanje njihovog kvaliteta do iznošenja na tržište. Ranije se kontrola etilena u hladnjačama vršila različitim tehnološkim postupcima, čije su osnovne karakteristike vezane za slabu efikasnost, komplikovanu proceduru i visoku cijenu aplikacije.Jedan od najstarijih reagensa koji se koristio za neutralisanje etilena je kalijum-permanganat ($KMnO_4$) (Gvozdenović i Davidović, 1990). Značajan iskorak u blokiranju djelovanja etilena na uskladišteno voće učinjen je uvođenjem 1-metilciklopropena (1-MCP). 1-MCP je gas slične hemijske strukture kao etilen, koji reaguje sa receptorima etilena na ćelijskom nivou brže nego sam etilen (Sisler i Serek, 1997). Na ovaj način se blokira dejstvo etilena, čime izostaje ili se značajno usporava aktivacija enzima koji dovode do senescencije plodova. Tretiranje klimakteričnog voća (jabuke i kruške) 1-MCP-om usporava procese sazrijevanja, ali ne sprečava u potpunosti smanjenje čvrstoće mesa ploda (Baritelle el al., 2001). Ovo jedinjenje utiče na intenzitet disanja u plodu (Fan i Mattheis, 1999; Xuan i Streif, 2005), čvrstoću mezokarpa ploda (Fan i Mattheis, 2001; Mir i Beaudry, 2001; De Ell et al.,2005; Magazin et al., 2012), smanjenje pojave brašnjavosti i stabilnost boje pokožice (Fan i Mattheis, 1999; Leverenntz et al., 2003; Crouch, 2003).

Omekšavanje plodova rezultat je razgradnje nerastvorljivog protopektina u rastvorljivi pektin ili hidrolize skroba (Mattoo et al., 1975). Smanjenje pektinskih supstanci u srednjoj lameli ćelijskog zida je vjerovatno ključni korak u procesu sarzijevanja plodova koji vodi gubitku cjelovitosti ćelijskog zida, a time i gubitku čvrstoće i omekšavanju (Solomos i Laties 1973). 1-MCP smanjuje gubitke u masi ploda i inhibira sintezu etilena, što u konačnici rezultira većom čvrstoćom mesa ploda (Jiang et al. 2001, Dong et al.,2002).Povećanje ukupno rastvorljive suhe tvari tokom skladištenja vjerovatno je rezultat razgradnje kompleksnih organskih metabolita u proste molekule, ili nastaje usljed hidrolize skroba u šećere (Wills et al.,1980).

Američka kompanija AgroFresh je otkupila pravo proizvodnje preparata na bazi 1-MCP-a i prvi njihov proizvod je dobio naziv SmartFresh™. SmartFresh™korišten u ovom radu je formulisan kao puder čija je aktivna materija (1-metilciklopropen) obložen alfa-ciklodekstrinom. Kada se stavi u vodu, SmartFresh™ odaje 1-MCP u okolni vazduh u vidu gasa. Dakle aplikacija se sastoji od punjenja komora voćem i postavljanja posuda sa vodom. Nakon toga se izračunava količina preparata koji će se dodati i to na osnovu zapremine komore, a zatim se u pripremljene posude sa vodom dodaje SmartFresh™. Tretman traje 24 sata na temperaturama od 0 do 20°C. Tretman se vrši samo jednom. Primijenjeni 1-MCP blokira receptore etilena na plodovima čime se produžava period njihovog skladištenja, smanjuje pojava fizioloških oboljenja i postiže bolji kvalitet nakon skladištenja. Smartfresh™ je danas dozvoljen za upotrebu u većini zemalja EU, Kanadi, Meksiku, Južnoafričkoj Republici, Novom Zelandu, Australiji, Izraelu i većini zemalja Južne Amerike.

Cilj rada je bio ispitati uticaj 1-MCP, kao inhibitora etilena- hormona zrenja na kvalitet i sposobnost skladištenja plodova kruške sorte 'Vilijamovka' u hladnjači sa normalnom atmosferom.

Materijal i metode

Zasad kruške iz kojeg su uzeti plodovi za analizu je u opštini Ilijaš, na 434 m nadmorske visine. Vodeća sorta u ovom zasadu je sorta'Vilijamovka', čiji su plodovi korišteni za analizu u ovom radu. Stabla sa kojih su uzimani plodovi se nalaze u osmoj godini uzgoja i kalemljena su na sijanac divlje kruške. Uzgojni oblik je vitko vreteno. Međuredni razmak iznosi 3,5 m, a redni 2 m.

Kao pokazatelji za određivanje optimalnog momenta berbe korišteni su veličina ploda i čvrstoća mesa ploda. Prema podacima CTIFL,optimalni momenat za berbu plodova sorte 'Vilijamovka'sa aspekta čvrstoće mesa ploda iznosi od 6,5 do 8,5 kg/cm^2 (Pašalić, 2004).Berbi plodova se pristupilo nakon mjerenja čvrstoće mesa ploda (u zasadu), a izmjerene vrijednosti suse nalazile u navedenom intervalu. Po završetku berbe na 30 plodova suu Laboratoriju za voćarstvo i vinogradarstvo Poljoprivredno – prehrambenog fakulteta Sarajevo izvršena mjerenja parametara kvaliteta ploda u momentu berbe. Parametri koji su mjereni u ovom radu su: čvrstoća mesa ploda (određena penetrometrom – Model GY-3, Top Instrument Co., Kina), boja pokožice ploda (određena kolorimetrom - Chroma meter CR – 400, Konica Minolta, Japan), sadržaj rastvorljive suhe tvari (određen refraktometrom - „Pocket“ refraktometar, Pal-α, Atago, Japan) i sadržaj ukupnih kiselina (metodom titracije sa 0,1M NaOH- indikator fenoftalein).

Ostatak plodova (120 plodova) je podijeljen u dvije skupine. Jedna skupina plodova je namjenjena za tretiranje1-MCP-om, a druga predstavlja kontrolne plodove.

Preparat SmartFresh^{TM} 0,14 Technology nabavljen je kao donacija firme Rohm and Hass iz SAD-a. Njegova primjena vršena je u skladu sa preporukama proizvođača, te na osnovu metode prema Magazin et al. (2012). Budući da se 1-MCP u toku primjene oslobađa u vidu gasa, ogled je vršen u hermetički zatvorenom plastičnom kontejneru od 120 l zapremine. Plodovi koji su korišteni u ovom ogledu su tretirani 2 dana nakon berbe. Ujednačeni plodovi bez spoljnih oštećenja su stavljani u mrežaste PVC džakove, tako da je ukupno bilo 6 džakova (za svaku oglednu varijantu tri ponavljanja) od po 20 plodova. Od togasu tri džaka smještena u plastični kontejner za tretiranje, a ostala tri su služili kao kontrola. Na osnovu zapremine kontejnera izračunata je potrebna količina preparata (120 mg preparata SmartFresh^{TM} 0,14 Technology) i destilovane vode (5 ml) da bi se dobila željena koncentracija gasa od 625 ppb. I preparat i voda su uz brzo miješanje sipani u manju plastičnu posudu koja je smještena u plastični kontejner, a isti je zatim hermetički zatvoren na 24 sata. Distribucija gasa u kontejneru je potpomognuta malim ventilatorom. Nakon 24 sata, tretirani i netretirani plodovi su smješteni u hladnjaču sa normalnom atmosferom (na temperaturu od 4°C i 90% vlažnosti zraka) i čuvani u periodu od dva mjeseca.

Nakon skladištenja plodovi su analizirani u pomenutom laboratoriju, a dobijeni podaci su obrađeni metodom analize varijanse korištenjem statističkog programaSPSS (Chicago, IL, USA) i primjenom analize osnovnih komponenti (PCA).

Rezultati i diskusija

Čvrstoća mesa ploda

Prosječne vrijednosti čvrstoće mesa ploda kruške 'Vilijamovka' prije i nakon skladištenja prikazane su u tabeli 1.

Prosječna čvrstoća mesa ploda se kretala od 8,38 kg/cm^2 prije skladištenja do 4,97 kg/cm^2 nakon dvomjesečnog skladištenja. Na osnovu rezultata prikazanih u tabeli 1. može se konstatovati da je tokom skladištenja došlo do signifikantnog pada čvrstoće mesa ploda, kako kod kontrolnih, tako i kod plodova tretiranih 1-MCP-om. Nakon dvomjesečnog skladištenja plodovi tretirani 1-MCP-om imali su značajno veću čvrstoću mesa u odnosu na netretirane plodove. To znači da je nakon skladištenja pad čvrstoće tretiranih plodova bio značajno manji u odnosu na pad kakav je zabilježen kod kontrolnih podova. Dobijeni rezultati su sukladni literaturnim izvorima (Crouch, 2003; Leverentz et al., 2003; Zanella, 2003; Magazin et al., 2012). Prema Mahajan i Dhatt (2004), najbolji konzumni kvalitet plodovi kruške imaju kada vrijednost čvrstoće ploda iznosi od 5,4 do 6,3 kg/cm^2 . Dakle, plodovi koji nisu tretirani 1-MCP-om nakon skadištenja ne posjeduju zadovoljavajući konzumni kvalitet sa aspekta čvrstoće mesa ploda.

Tabela 1. Čvrstoća mesa (kg/cm^2) ploda kruške'Vilijamovka' prije i nakon skladištenja.
Fruit flesh firmness (kg/cm^2) of 'Williams' pear cultivar before and after cold storage.

Termin *Term*	Kontrola *Control* $\bar{x}$ ± Sd	1-MCP $\bar{x}$ ± Sd	Prosjek termin *Average for term* $\bar{x}$ ± Sd
Prije skladištenja/ *Before storage*	8,38 a ± 0,51	8,38 a ± 0,51	8,38 a ± 0,51
Poslije skladištenja / *After storage*	3,70 c ±1,43	6,86 b ± 0,90	4,97 b ± 2,00
Prosjek tretman / *Average for treatment*	5,74 b ± 2,76	7,83 a ± 1,23	

Ukupna rastvorljiva suha materija

Vrijednosti ukupne rastvorljive materije u plodovima kruške 'Vilijamovka' prikazane su u tabeli 2.

Tabela 2. Sadržaj ukupnerastvorljive suhe materije u plodovima kruške 'Vilijamovka' prije i nakon skladištenja.
Total soluble solids content (°Brix) in 'Williams' pear fruitsbefore and after storage.

Termin *Term*	Kontrola *Control* $\bar{x}$ ± Sd	1-MCP $\bar{x}$ ± Sd	Prosjek termin *Average for term* $\bar{x}$ ± Sd
Prije skladištenja/ *Before storage*	15,03b ± 0,64	15,03b ± 0,64	15,03 ± 0,57
Poslije skladištenja / *After storage*	17,13a ± 0,13	15,50b ± 0,95	16,58 ± 0,95
Prosjek tretman / *Average for treatment*	16,43a ± 1,10	15,26a ± 0,77	

Prosječan sadržaj ukupne rastvorljive suhe materije u plodovima kruške 'Vilijamovka' je prije skladištenja bio 15,03°Brix-a, a nakon skladištenja je bio 16,58°Brix-a.Kod kontrolnih plodova tokom skladištenja je došlo do signifikantnog povećanja suhe tvari, u odnosu na plodove tretirane 1-MCP,kod kojih tokom skladištenja ovo povećanje nije bilo statistički značajno. Sličan efekat 1-MCP na sadržaj ukupne rastvorljive suhe tvari je ostvaren kod dunje (Kaynas et al., 2012).

Ukupne kiseline

Prosječan sadržaj organskih kiselina u plodovima kruške 'Vilijamovka' se kretao od 4,13 g/l prije unošenja u skladište do 3,68 g/l, koliko je u prosjeku izmjereno nakon skladištenja. Prosječan sadržaj kiselina u analiziranim plodovima je značajno opadao tokom skladištenja. Nakon dvomjesečnog skladištenja plodovi tretirani 1-MCP-om imali su značajno veći sadržaj kiselina odnosu na netretirane plodove. To znači da je nakon skladištenja pad sadržaja kiselina bio značajno manji u odnosu na pad kakav je zabilježen kod kontrolnih plodova. Do sličnih rezultata su došli Kaynas et al. (2012) u istraživanjima o uticaju 1-MCP-a na očuvanje kvaliteta dunje.

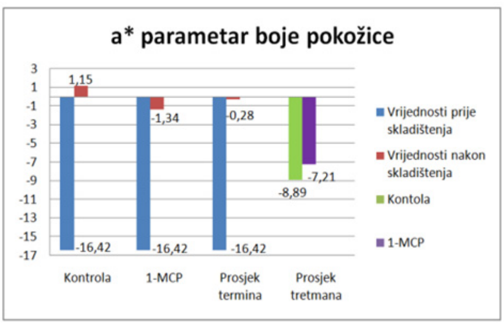
Tabela 3. Sadržaj ukupnihkiselina lodovima kruške 'Vilijamovka' prije i nakon skladištenja.
Content of titrable acids (g/l) of 'Williams' pearfruits before and after storage.

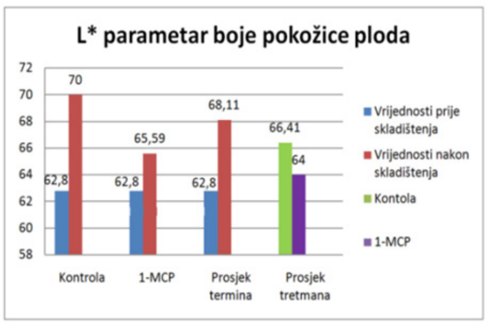
Termin *Term*	Kontrola *Control* $\bar{x} \pm$ Sd	1-MCP $\bar{x} \pm$ Sd	Prosjek termin *Average for term* $\bar{x} \pm$ Sd
Prije skladištenja/ *Before storage*	4.13a ± 0.19	4.13a ± 0.19	4.13a ± 0.18
Poslije skladištenja / *After storage*	3.56c± 0.30	3.89b ± 0.19	3.68b ± 0.25
Prosjek tretman / *Average for treatment*	3.75b ± 0.25	4.01a ± 0.22	

Plodovi tretirani sa 1-MCP održavaju veći sadržaj kiselina tokom skladištenja usljed odgađanja procesa dozrijevanja.

Boja pokožice ploda

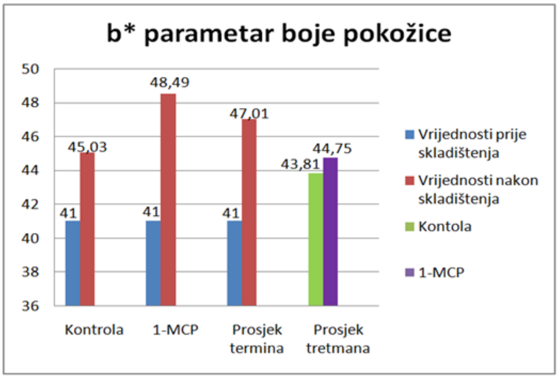
Test analize varijanse je pokazao da je samo termin mjerenja imao signifikantan uticaj na kolorimetrijski određene parametre boje pokožice ploda (L* a* b*). Sve vrijednosti parametara boje pokožice ploda nakon skladištenja su bile značajno veće u odnosu na vrijednosti prije skladištenja. Nije bilo značajnog uticaja tretmana 1-MCP-om na posmatrano obilježje (grafikoni 1, 2 i 3).





Grafikon 1. a* vrijednosti boje pokožice ploda kruške Vilijamovka.
a values of fruit skin color of 'Williams' pear.*

Grafikon 2. L* vrijednosti boje pokožice ploda kruške Vilijamovka.
L values of fruit skin colorof 'Williams' pear.*



Grafikon 3. b* vrijednosti boje pokožice ploda kruške 'Vilijamovka.
b values of fruit skin color of 'Williams' pear.*

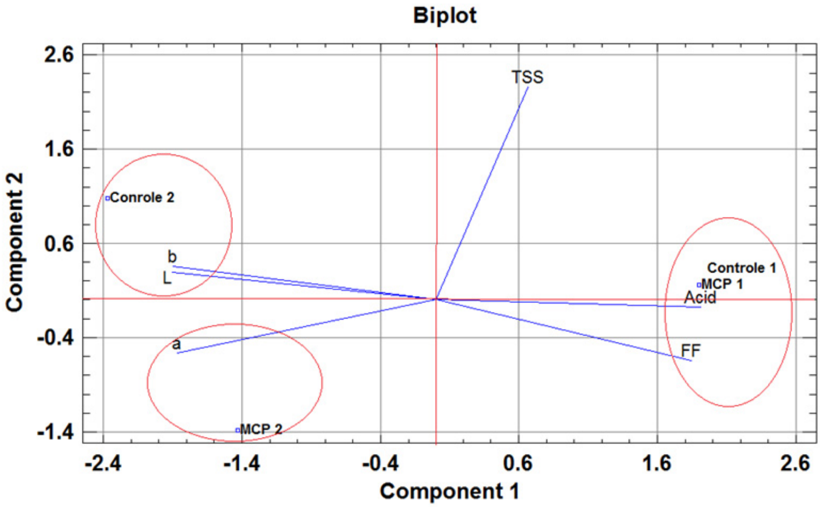
Analiza osnovnih komponenti (PCA) parametara kvaliteta ploda kruške 'Vilijamovka' u zavisnosti od skladištenja i tretmana MCP-om

Rezultati PCA analize su predstavljeni tabelom 4 i grafikonom 4.

Tabela 4. Broj osnovnih komponenti u PCA analizi.
Number of principal components in PCA analysis.

Broj komponente *Component number*	Svojstvena vrijednost *Eigenvalue*	% variranja *% ofvariance*	Kumulativniprocenat *Cumulative percentage*
1	4.95924	82.654	82.654
2	1.04076	17.346	100.000
3	4.30828E-16	0.000	100.000

Da bi se dobio uvid u promjene plodova kruške 'Vilijamovke' prije i nakon skladištenja, kao i između kontrolnih plodova ove sorte i plodova tretiranih 1-MCP-om prije skladištenja, urađena je analiza osnovnih komponenti (Principal Component Analysis-PCA) ispitivanih fizičko-hemijskih parametara ploda (tabela 4). Pošto je tzv. svojstvena vrijednost ili latentni korijen (eigenvalue) imala veću vrijednost od 1 za dvije osnovne komponente, PCA je predstavljena sa jednim biplotom (grafikon 4). Sa ove dvije komponete je objašnjeno 100% varijabilnosti, pri čemu je komponentom 1 objašnjeno 82,65%, a komponentom 2 17,35% varijabilnosti.



Grafikon 4. Analiza osnovnih komponenti (PCA).
Principal component analysis (PCA).

Pozitivni dio komponente 1 je determinisan čvrstoćom mesa ploda i sadržajem kiselina u plodu, a njen negativni dio je dominatno određen parametrima boje pokožice (L*a*b). Pozitivni dio komponente 2 je dominantno određen sadržajem ukupno rastvorljive suhe tvari i svjetloćom boje ploda (L*), te sadržajem ukupno rastvorljive suhe tvari, a negativni dio ove komponente je određen parametrom a* boje pokožice, kao i čvrstoćom mesa ploda. Iz grafikona 4 je vidljivo da su plodovi sorte 'Vilijamovka' prije skladištenja i prije tretmana sa 1-MCP-om jedini smješteni na desnoj strani biplota, što znači da su ovi plodovi određeni uglavnom varijablama determinisanim sa pozitivnim dijelom komponente 1, a to su čvrstoća mesa ploda i sadržaj kiselina u plodu. Plodovi kruške nakon skladištenja se nalaze u negativnom dijelu komponente 1, a to znači da su određeni višim sadržajem ukupno rastvorljive suhe tvari, a nižim sadržajem kiselina i manjom čvrstoćom mesa ploda, u odnosu na plodove prije skladištenja. Plodovi kruške 'Vilijamovke' koji prije skladištenja nisu tretirani 1-MCP-om se nalaze u negativnom dijelu komponente 1, ali u pozitivnom dijelu komponente 2. To znači da se ovi plodovi izdvajaju visokim sadržajem ukupno rastvorljive tvari, a niskim sadržajem kiselina u plodu i niskom čvrstoćom mesa ploda. To ukazuje da je kod tih plodova tokom skladištenja došlo do ubrzanog dozrijevanja. Na ovo upućuje i promjena parametara boje pokožice ploda.

Međutim, plodovi kruške 'Vilijamovke' koji su prije skladištenja tretirani 1-MCP-om nalaze se u negativnom dijelu komponenti 1 i 2. To znači da kod tretiranih plodova tokom skladištenja nije došlo do intenzivnog rasta ukupne rastvorljive suhe tvari kao kod kontrolnih plodova, ali ti plodovi nakon skladištenja imaju i veću čvrstoću mesa u odnosu na netretirane plodove.

Zaključak

Na osnovu dobijenih rezultata može se dati preporuka za primjenu tretmana 1-MCP-omprije skladištenja plodova kruške sorte'Vilijamovka'. Ovaj tretman se pokazao učinkovitim na očuvanje kvaliteta ploda s obzirom na parametre čvrstoće mesa ploda, sadržaja ukupno rastvorljive suhe tvari i organskih kiselina. To znači da su plodovi tretirani 1-MCP-om imali sporije dozrijevanje i sporiji pad kvaliteta tokom dvomjesečnog skladištenja u uslovima hladnjače sa normalnom atmosferom.

Acknowledgement

We accknowledge to RandH’s for kindly contribution to research work of this manuscript.

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Influence of 1-Methylcyclopropene (1-MCP) on Fruit Cold Storage of 'Williams' Pear Variety

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Summary

The objective of this research was to investigate the effect oftreatment with 1-MCP on storage and fruit quality changes of'Williams' pear cultivar. Pear fruits were treated with 1-MCP (SmartfreshTM; 0.14% MCP) with concentration of 625 ppb for 24 hours and were stored for two months at 4°C temperature and 85–90% relative humidity conditions (NA storage room). Some quality parameters such as fruit firmness, total soluble solids, titratable acidity and fruit skin colour (alalyzed colorimetrically) were measured before postharvest treatment of 1-MCP and after storage period of 60 days. The obtained results indicated that 1-MCP treatment were effective on the rate of softening, increase of total soluble solids and decrease of titratable acids. 1-MCP did not influeced the change of fruit skin color. On the basis of obtained results in this study, 1-MCP could be recommended as a potential tool to delay ripening and enhance pear fruit quality during 60 days of cold storage.

Keywords: 1-methylcyclopropen (1-MCP),storage, pear, fruit quality, SmartFresh.

Originalni naučni rad

OŽILJAVANJE ZRELIH REZNICA SMOKVE (*Ficus carica* L.)

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Izvod. U ovom radu su prikazani rezultati egzogene primjene različitih koncentracija indol-buterne kiseline (IBA) i alfa-naftil sirćetne kiseline (NAA) na procenat ožiljavanja zrelih reznica u šest sorti smokve. Konstatovan je različit uticaj egzogene primjene fitohormona IBA (1000, 2000, 3000, 4000 *ppm*) i NAA 0,5% na uspješnost ožiljavanja zrelih reznica smokve. Najniže prosječne vrijednosti ožiljavanja konstatovane su u reznica koje nisu tretirane fitohormonima (kontrola) kod svih ispitivanih sorti smokve, a zatim kod reznica koje su tretirane sa fitohormonom NAA 0,5%. Najbolje ožiljavanje zrelih reznica smokve zabilježeno je primjenom IBA u koncentraciji od 4000 *ppm* i iznosilo je za sve sorte iz ogleda (89,25%,) a najslabije ožiljavanje je registrovano kod reznica koje nisu tretirane fitohormonom (71,94%). Od ispitivanih sorti smokve, kod svih primjenjenih tretmana, jednorodna sorta „Rezavica“ se najbolje ožiljavala (85,14%), a najslabije dvorodna sorta „Petrovača crna“.

Povećanje procenta ožiljavanja zrelih reznica je konstatovano kod svih ispitivanih sorti smokve, srazmjerno povećanju koncentracije rastvora IBA, Analizom varijanse i LSD testom konstatovane su statističke razlike između ispitivanih sorti smokve, gdje uspjeh ožiljavanja zavisi od egzogenog tretiranja reznica različiti vrstama i koncentracijama fitohormona. Upotreba većih koncentracija IBA (3000 i 4000 *ppm*) pokazala se najboljom i kao takva se može preporučiti u tehnologiji proizvodnje sadnica smokve na vlastitom korijenu.

Ključne riječi: smokva, sorta, reznica, fitohormon, ožiljavanje.

Uvod

Sadni materijal je vrlo značajan činilac za uspješnu i rentabilnu proizvodnju smokve. Da bi se postigli najvažniji ciljevi da se sadnice prime i da uspješno rastu, da rano prorode i redovno rađaju, da daju plodove visokog kvaliteta, da su dugovječne i otporne prema prouzrokovačima bolesti i štetočinama, one moraju da budu proizvedene od zdravih, selekcionisanih i kontrolisanih podloga i sorti. Plantažne zasade smokve, kao i sadnju na okućnicama treba podizati sadnim materijalom koji je sortno čist i sa dobro razvijenim nadzemnim sistemom i zdravim korijenovim sistemom, s posebnim osvrtom na viroze i druge opasnije karantinske bolesti i štetočine.

Sadnice smokve mogu se proizvesti vegetativnim putem na različite načine: ožiljavanjem zrelih i zelenih reznica, mikro razmnožavanjem "*in vitro*", kalemljenjem sijanaca smokve, i generativnim putem iz sjemena. Razmnožavanje zrelim odrvenjelim reznicama je najrašireniji način razmnožavanaja smokve u svijetu i kod nas. Ona ima izrazitu sposobnost reparacije gdje od različitih biljnih organa (korijena i grančica) u pogodnom supstratu formira adventivni korijen. Ta sposobnost uslovljena je prisustvom grupe specifičnih parenhimskih ćelija, koje se mogu dijeliti, nazvanih začeci adventivnih korijena koji se nalaze izmedju ksilema i floema, prvenstveno na mjestima na kojima se široki primarni sržni začeci susreću sa kambijumom (Stanković i Savić, 1978).

Reznice su vegetativni dijelovi biljke, koji iz godišnjeg prirasta (zelene reznice) ili iz prošlogodišnjih izbojaka (zrele reznice) u povoljnim i kontrolisanim uslovima iz bazalnog dijela razvijaju korijen (Hartmann i Kester,1965).Mladari koji se upotrebljavaju moraju biti potpuno dozreli, normalno razvijeni, debljine iznad 5 mm, jer tanji nisu pogodni jer su obično siromašni rezervnim materijama i slabo se ožiljavaju (Hadžiabulić, 2010).

U praksi se pokazalo da se smokva dobro ožiljava reznicama, ali egozogenom primjenom fitosintetičkih hormonalnih materija dobije se znatno veći procenat ožiljavanja, jači i razgranatiji korijenov sistem. Sve biljke prirodno sadrže hemijske supstance (fitohormone), koje pozitivno utiču na njihov rast i razvoj. Ove prirodne supstance, zahvaljujući razvoju novih tehnologija, posljednjih godina se proizvode i sintetičkim putem. Dakle, njihovim dodavanjem vještački se izazivaju procesi rizogeneze. Hormoni utiču na novu emisiju korijena. Intenzitet razvoja korijena zavisi više ili manje od energije sa kojom ulazi reznica u proces ožiljavanja.

U rasadničkoj proizvodnji su naročito značajni uspjesi postignuti korišćenjem sintetičkih fitohormonalnih materija indol-buterne kiseline (IBA) i alfa-naftil sirćetne kiseline (NAA) u različitim koncetracijama. Vještačko dodavanje egsogenih fitohormonalnih materija u proizvodnji voćnog sadnog materijala izaziva mnogobrojne korisne reakcije, koje utiču na stimulisanje razvoja kalusa u bazalnim zonama ožiljavanih reznica, a koje zavise od vremena tretiranja, količine i načina dodavanja (Nikolić i Radulović, 2010).

Ožiljavanje reznica zavisi od unutrašnjih relativnih činilaca (stadijuma, mladosti reznice i razvijenosti grančice) i od spoljašnjih činilaca: svetlosti, objekta (plastenika ili staklenika), supstrata, temperature, vlažnosti, vremena postavljanja reznica i vrste i doze tretiranja sa biostimulatorima rastenja (Grbić, 2004).

Primjena sintetičkih fitohormona u procesu ožiljavanja zrelih reznica smokava u svijetu i kod nas je manje ispitivana nego na ostalim voćnim vrstama. U domaćoj i stranoj literaturi mogu se naći samo fragmentarni podaci koji obrađuju problematiku ožiljavanja drvenastih reznica, od kojih navodimo najznačajnije autore: Popović (1997), Sahrad (2007), Prgomet (2014), Hadžiabulić (2010) i dr.

Cilj ovog istraživanja je da se utvrdi koji egzogeni fitohormoni i koje koncentracije primjenjenih fitohormona indol – buterne kiseline (IBA) i alfa – naftil sirćetne kiseline (NAA) najbolje utiču i djeluju na proces rizogeneze smokve radi dobivanja kvalitetnih sadnica i smanjenja troškova proizvodnje.

Materijal i metode

Ispitivanje uticaja primjene egzogenih fitosintetičkih hormona indol- 3 - buterne kiseline (IBA) i alfa- naftil sirćetne kiseline (NAA) na rizogenezu zrelih reznica kod šest sorti smokve obavljeno je u plasteniku rasadnika „ Čuljak’’ u Čapljini u toku 2013 godine.

Za ožiljavanje su korištene jednogodišnje zrele reznice šest sorti smokve: „Petrovača bijela“, „Petrovača crna“ i „Sulatanija crna“ (dvorotke) i 3 sorte jednorotke: „Sušilica“, „Rezavica“ i „Termenjača“. One su uzete sa matičnih stabala smokve u februaru 2013. godine. Do momenta prporenja reznice su čuvane u PVC kesama u hladnjači na temperaturi od 3°C i pri relativnoj vlažnosti vazduha od 90%. Dužina reznica se kretala od 15-20 cm, debljina oko 10 mm, zavisno od dužine internodija i broja pupoljaka.

Reznice su prorene u agroperlit 10.03.2013. godine. U bazalnom dijelu reznice pravljen je kosi rez na suprotnoj strani osnovnog pupoljka radi povećanja aktivne dodirne površine i fitohormona IBA i NAA, a zatim je izvršeno naranjavanje epidermisa radi bržeg kalusiranja. Prije tretiranja rizogenom supstancom, bazni dio reznice je tretiran fungicidom Zato 0,1% radi preventive protiv gljivičnih bolesti. Donji (bazalni) dio reznica je uranjan u tečni rastvor IBA (konc. 1000, 2000, 3000, 4000 *ppm*) i u rastvoru je držan 30 sekundi, a zatim sušen 30 minuta na sobnoj temperaturi, da bi se poslije ove tehnološke mjere reznice prporile u supstrat od riječnog pijeska (50%) i agroperlita (50%). Reznice su umakane u praškasti NAA 0,5% i prporene u supstrat. Reznice u kontrolnoj varijanti nisu tretirane ni jednim navedenim fitohormonom.

Reznice su prporene na razmaku 5 x 5 cm, a dubina prporenja je iznosila 10-15 cm. Temperatura supstrata u toku ožiljavanja je iznosila 20-24°C, a vlažnost vazduha u plasteniku je bila 90%. U toku procesa ožiljavanja konstantno je funkcionisao sistem nebulizacije, stvarajući odgovarajuću vlažnost supstrata i vazduha u plasteniku.

Postavljen je dvofaktorijalni ogled sa 6 sorti u 4 ponavljanja i u 4 različite koncentracije IBA i jednoj koncentraciji NAA. Dobijeni rezultati istraživanja statistički su obrađeni analizom varijanse, a ocjena značajnosti razlika je određena po LSD testu.

Rezultati i diskusija

Rezultati ispitivanja uticaja indol-3-buterne kiseline (IBA) i alfa-naftil sirćetne kiseline (NAA) na procenat ožiljavanja zrelih reznica ispitivanih sorti smokve prikazani su u tabelama 1 – 8.

Najniže prosječne vrijednosti ožiljavanja kod svih ispitivanih sorti smokve konstatovane su kod reznica koje nisu tretirane fitohormonima (kontrola). Prosječna vrijednost ožiljavanja kontrolnih reznica kod ispitivanih sorti iznosila je 71,94%, pri čemu je najmanja vrijednost registrovana u sorte „Petrovače crne“ (68,33%), a najviša u sorte „Rezavice“ (75,00%).

Tabela 1. Prosječna vrijednost ožiljavanja (%) ispitivnih sorti smokve sa rastvorima indol-3 buterne kiseline (IBA) i alfa-naftil sirćetnom kiselinom (NAA).
Average value of rooting (%) of studied fig cultivars affected by Indole-3-butyric acid (IBA), and alpha-naphthyl acetic acid (NAA).

Sorta *Cultivar*	Kontrola *Control*	NAA 0.5%	IBA/*ppm*					$\overline{X}$
			1000	2000	3000	4000	$\overline{X}$	
Petrovača bijela	71,67	85,83	81,67	83,33	85,83	88,32	84,79	82,78
Petrovača crna	68,33	83,33	80,83	82,50	84,17	86,67	83,54	80,97
Sultanija crna	73,33	86,66	82,50	84,17	86,66	89,98	85,83	83,88
Sušilica	72,50	83,33	83,33	84,16	85,83	90,50	85,96	83,28
Rezavica	75,00	87,49	83,33	85,83	87,49	91,67	87,08	85,14
Termenjača	70,83	81,33	80,83	83,33	86,66	88,33	84,79	81,89
$\overline{X}$	71,94	84,66	82,08	83,89	86,11	89,25	85,33	

Prosječna vrijednost ožiljenih reznica ispitivanih sorti smokve koje su tretirane fitohormonom NAA 0,5% iznosila je 84,66%. Prosječne vrijednosti ožiljavanja reznica primjenom fitohormona IBA kretale su se od 80,83% kod „Petrovače crne“ i „Termenjače“ (IBA-1000 *ppm*) do 91,67% kod „Rezavice“ (IBA-4000 *ppm*). Prosječna vrijednost procenta ožiljenih reznica smokve za sve ispitivane sorte u svim koncentracijama IBA iznosila je 85,33% - tab.1.

Analiza varijanse prosječne vrijednosti ožiljenih reznica ispitivanih sorti smokve predstavljena je u Tabeli 2.

Tabela 2. Analiza varijanse prosječne vrijednosti ožiljenih reznica za cijeli ogled.
Analysis of variance of average values for rooted cuttings for the whole tour.

Izvor varijacije *Source of variation*	Prosječna vrijednost ožiljenih reznica *Average values of rooted cuttings*				
	DF	SS	MS	F	p-level
Sorta (A) *Cultivar*	5	259.731	51.9461	2.78	0.0211 **
Tretman (B) *Treatment*	5	4206.95	841.391	45.05	0.0000 **
A*B	25	99.4078	3.97631	0.21	1.0000 ns
Residual	108	2017.14	18.6773		
Total	143	6583.24			

Prema svim ispitivanim parametrima za cijeli ogled (Tabela 2) za primjenjene fitohormone u procesu rizogeneze reznica smokve, ustanovljena je statistički visoko značajna razlika u uspješnosti ožiljavanja, posmatrano po sortama i tretmanima.

U tabelama 3. i 4. dat je prikaz analize varijanse za ožiljavanja reznica ispitivanih sorti smokve bez egzogene primjene sintetičkih fitohormona (kontrola) i uticaj sorti smokve na proces rizogeneze bez tretiranja fitohormonom.

Tabela 3. Analiza varijanse prosječne vrijednosti ožiljavanja reznica bez primjene fitohormona (kontrola).
Analysis of variance of average values for rooted cuttings without the use of phytohormones (control).

Izvor varijacije *Source of variation*	Kontrola / *Control* Sorta (A) / *Cultivar*				
	DF	SS	MS	F	p-level
Sorta (A) / *Cultivar*	5	103,774	20.7548	1.64	0.2001 ns
Residual	18	227,739	12.6522		
Total	23	331,513			

Tabela 4. Uticaj sorti smokve na proces rizogeneze bez tretiranja fitohormonom.
Impact of fig cultivars on the rhizogenesis process without phytohormone treatment.

Sorta *Cultivar*	Petrovača bijela	Petrovača crna	Sultanija crna	Sušilica	Rezavica	Termenjača	$\overline{X}$
Kontrola *Control*	71,67 ab[1]; a[2]	68,33 b; a	73,33 ab; a	72,50 ab; a	75,00 a; a	70,83 ab; a	*71,94*

[1] Vrijednosti obilježene različitim slovima statistički su značajno različite na nivou P < 0,05 (LSD test) = 5,2842;
[2] Vrijednosti obilježene različitim slovima statistički su značajno različite na nivou P < 0,01 (LSD test) = 7,2398.

Dobijeni rezultati ožiljavanja reznica smokve bez primjene fitohormona (kontrola) pokazuju osobinu da se i bez egzogene primjene sintetičkih stimulatora rasta može postići relativno visok procenat ožiljavanja kod ispitivanih sorti smokve (Tabela 4).

Za prag značajnosti 0.05 je zabilježena razlika u ožiljavanju među sortama, pri čemu sorta „Rezavica“ pokazuje najbolju sposobnost ožiljavanja bez tretiranja fitohormonom (75,00%), a „Petrovača crna“ najslabiju (68,33%). Nisu zapažene statistički značajne razlike među ispitivanim sortama smokve za prag značajnosti 0.01.

Dobijeni rezultati su slični rezultatima Popovića (1997), koji je konstatovao da se zrele reznice smokve dobro ožiljavaju i bez primjene fitohormona, gdje je registrovan visok procenat ožiljavanja kod sorti „Rezavica“ (78,70%) i „Zimnica“ (81,20%).

Rezultati analize varijanse pokazuju da primjena fitohormona NAA 0,5% u ožiljavanju smokve (Tabela 5) nije imala statističku značajnost kod ispitivanih sorti.

Poređenje razlika procenata ožiljenih reznica tretiranih fitohormonom NAA 0,5% prikazani su u tabelama 5 i 6. Takođe, slovima su predstavljene sličnosti na nivou sorti za prag značajnosti 0,05 i 0,01 (LSD test).

Tabela 5. Analiza varijanse prosečnih vrijednosti ožiljavanja reznica ispitivanih sorti smokve tretiranih fitohormonom NAA
Analysis of variance of average values for rooted cuttings of tested fig cultivars treated by phytohormones NAA

Izvor varijacije *Source of variation*	Fitohormon NAA 0.5% / *Phytohormone NAA* Sorta (A) / *Cultivar*				
	DF	SS	MS	F	p-level
Sorta (A) /*Cultivar*	5	111.991	22.3983	1.16	0.3682 ns
Residual	18	348.823	19.3791		
Total	23	460.814			

Tabela 6. Uticaj fitohormona NAA 0,5% na proces rizogeneze isptivanih sorti smokve.
Influence of phytohormone NAA 0.5% in the process of rhizogenesis of tested fig cultivars

Sorta	Petrovača bijela	Petrovača crna	Sultanija crna	Sušilica	Rezavica	Termenjača	$\overline{X}$
Kontrola	85,83 a[1]; a[2]	83,33 a; a	86,66 a; a	83,33 a; a	87,49 a; a	81,33 a; a	84,66

[1] Vrijednosti obilježene različitim slovima statistički su značajno različite na nivou P < 0,05 (LSD test)) = 6,5398;
[2] Vrijednosti obilježene različitim slovima statistički su značajno različite na nivou P < 0,01 (LSD test) = 8,9600.

Rezultati prikazani u tabeli 6 ukazuju da je najmanji procenat ožiljavanja registrovan kod jednorodne sorte „Termenjače“ (81,33%), a najveći kod sorte „Rezavica“ (87,49%) pod uticajem fitohormona NAA. Međutim, između ispitivanih sorti nisu uočene statistički značajne razlike u dobijenim vrednostima.

U tabeli 7. prikazana je analiza varijanse za prosječnu vrijednost ožiljavanja reznica ispitivanih sorti, tretiranih različitim koncentracijama fitohormona IBA.

Tabela 7. Analiza varijanse prosječnih vrijednosti ožiljavanja reznica sorti smokve, tretiranih fitohormonom IBA u koncentracijama od 1000, 2000, 3000 i 4000 *ppm.*
Analysis of variance of average values for rooted cuttings of tested fig cultivars treated by phytohormone IBA at concentrations of 1000, 2000, 3000 and 4000 ppm.

Izvor varijacije *Source of variation*	Fitohormon IBA (ppm) / *Phytohormone* Sorta (A) / *Cultivar* Koncentracija (B) / *Concentration*				
	DF	*SS*	*MS*	*F*	*p-level*
Sorta (A) / *Cultivar*	5	119.854	23.9707	1.20	0.3189 ns
Koncentracija (B) *Concentration*	3	685.658	228.553	11.42	0.0000 **
*A*B*	15	23.5194	1.56796	0.08	1.0000 ns
Residual	72	1440.58	20.0081		
Total	95	2269.61			

Tabela 8. Uticaj koncentracije IBA na proces rizogeneze ispitivanih sorti smokve.
Effect of IBA concentration on the process of rhizogenesis of tested fig cultivars.

Sorta / *Cultivar*	IBA/*ppm*				$\overline{X}$
	1000	2000	3000	4000	
Petrovača bijela	81,67	83,33	85,83	88,32	84,79 ab[1]; a[2]
Petrovača crna	80,83	82,50	84,17	86,67	83,54 b; a
Sultanija crna	82,50	84,17	86,66	89,98	85,83 ab; a
Sušilica	83,33	84,16	85,83	90,50	85,96 ab; a
Rezavica	83,33	85,83	87,49	91,67	87,08 a; a
Termenjača	80,83	83,33	86,66	88,33	84,79 ab; a
$\overline{X}$		83,89 bc; bc	86,11 b; ab	89,25 a; a	

[1] Vrijednosti obilježene različitim slovima statistički su značajne na nivou P < 0,05 (LSD test);
[2] Vrijednosti obilježene različitim slovima statistički su značajne na nivou P < 0,01 (LSD test)

Na osnovu rezultata analize varijanse (Tabela 7) može se konstatovati da su ispoljene značajne statističke razlike u ožiljavanju reznica primjenom različitih koncentracija fitohormona IBA. Međutim, nema značajnih statističkih razlika u ožiljavanju reznica primjenom IBA među ispitivanim sortama smokve, kao i pri interakciji ova dva faktora (sorta i koncentracija).

U tabeli 8. su dati rezultati poređenja razlika procenata ožiljavanja reznica ispitivanih sorti smokve, tretiranih različitim koncentracijama fitohormona IBA.

Primjena različitih koncentracija fitohormona IBA uticala je na različit procenat ožiljavanja reznica ispitivanih sorti smokve, pri čemu su ispoljene statistički visoko značajne razlike među svim tretmanima. Primjenjena najveća koncentracija rastvora IBA-4000 *ppm* je u odnosu na ostale koncentracije rastvora IBA pokazala najbolju rizogenezu.

U istraživanju nisu ispoljene statistički značajne razlike među sortama za vrijednost najmanje značajnosti od $P<0,05$ i $P<0,01$ prema LSD testu.

Popović (1997) i Sahrad (2007) navode da je najbolje ožiljavanje postignuto sa većim koncentracijama IBA, što je u saglasnosti sa dobivenim rezultatima u ovom radu.

Zaključak

Na osnovu dobijenih rezultata mogu se izvesti sljedeći zaključci:

Konstatovan je različit uticaj egzogene primjene fitohormona IBA (koncentracije:1000, 2000, 3000, 4000 ppm) i NAA 0,5% na uspješnost ožiljavanja zrelih reznica smokve. Najniže prosječne vrijednosti ožiljavanja konstatovane su u reznica koje nisu tretirane fitohormonima (kontrola) kod svih ispitivanih sorti smokve. Prosječna vrijednost ožiljavanja kontrolnih reznica kod ispitivanih sorti iznosila je 71,94%, a najmanja vrijednost bila je 68,63% kod sorte „Petrovače crne“. Najveća prosječna vrijednost registrovana je kod sorte „Rezavice“ (75%). Dobijeni rezultati ožiljavanja reznica smokve bez primjene fitohormona (kontrola) pokazuju osobinu da se i bez egzogene primjene sintetičkih stimulatora rasta može postići relativno visok procenat ožiljavanja reznica.

Najbolje ožiljavanje zrelih reznica smokve je registrovano kod reznica koje su tretirane sa IBA u koncentraciji od 4000 *ppm* i prosečno je iznosilo za sve sorte ogleda 89,25%, a najslabije ožiljavanje registrovano je kod primjene IBA, koncentracije rastvora od 1000 *ppm* i iznosilo je za sve sorte ogleda 82,08%. Jednorodna sorta „Rezavica“ se najbolje ožiljavala (85,14%), a najslabije dvorodna sorta „Petrovača crna“ (80,97%). Konstatovano je kod svih ispitivanih sorti smokve povećanje procenta ožiljavanja zrelih reznica, srazmjerno povećanju koncentracije rastvora IBA, kojom su tretirane reznice ispitivanih sorti.

Rezultati analize varijanse pokazuju da primjena fitohormona NAA 0,5% u ožiljavanju smokve nije imala statističku značajnost kod ispitivanih sorti smokve, gdje je najbolje ožiljavanje registrovano kod jednorodne sorte „Rezavice“ (87,49%), a najslabije kod jednorodne sorte „Termenjače“ (81,33%).

Upotreba većih koncentracija IBA (3000, 4000 *ppm*) pokazala se najboljom i kao takva se može preporučiti u tehnologiji proizvodnje sadnica smokve na vlastitom korijenu.

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Root Taking of Mature Fig (*Ficus carica* L.) Tree Shoots

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Summary

This paper presents the results of applying different concentration of exogenous indole-butyric acid (IBA) and Alpha-naphthyl acetic acid (NAA) on rooting of mature cuttings in six varieties of figs. Ascertained the different effects of exogenous application of phytohormones IBA (1000, 2000, 3000, 4000 ppm) and NAA 0.5% on the success of rooting of mature cuttings of fig. The lowest average values were found in the rooting of cuttings which are not treated with phytohormones (control) for all tested varieties figs, and then with the cuttings treated with phytohormones NAA 0.5%.

Rooting cuttings of ripe figs recorded by applying IBA at a concentration of 4000 ppm and accounted for all varieties from the trial (89.25%) and the lowest was registered in rooting cuttings that are not treated with phytohormones (71.94%). The cultivar figs, with all the applied treatment, homogeneous variety "Rezavica" the best ožiljavala (85.14%) and least two-fold varieties "Petrovaca Black".

Increase the percentage of rooting of mature cuttings was noted in all tested varieties of figs, in proportion to the increase in the concentration of IBA solution, analysis of variance and LSD test were found statistical differences between the varieties of figs, where success depends on rooting cuttings of exogenous treating different types and concentrations of phytohormones.

The use of higher concentrations of IBA (3000 and 4000 ppm) proved to be the best, and as such can be recommended in technology production plants figs on its own root.

Keywords: fig, grape variety, cuttings, phytohormones, rooting.