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GROWING DECIDUOUS FRUIT TREES IN TROPICAL REGIONS LACKING WINTER CHILLING

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1. Executive summary

The following is the Israeli final report. It is submitted after a long delay due to our wish to submit a combined report with that of the Kenyan collaborators. Inspite of repeated requests, the Kenyan report was not obtained by the time of submitting this report.

In this project we wanted to demonstrate the potential of growing commercially deciduous fruit trees in tropical climates and to prove that bud break and fruit development is possible without exposure of the dormant buds to chilling.

In Kenya, use of the techniques recommended in the project namely defoliation followed by rest-breaking chemicals, led to a relatively good bud break in mature trees with private growers as well as with young orchard planted through this project. Production of fruit was obtained especially of apples. Change of the Kenyan collaborator affected the project as the interest on the Kenyan side was not strong enough to initiate spreading of the experiments into more available orchards. The experimental orchard in Nyeri should be kept as a demonstration plot for interested farmers in the region as well as country wide.

In The Horticultural Research Center in Thika the field know-how of treating the trees in the field as well as objective means of evaluation are expected to generate continuous interest in helping the development of local production of the highly evaluated deciduous fruits especially the apple. Use of rest-breaking chemicals with special attention to timing of application as well as treating the apple orchard on an annual basis were skills learned by the Kenyan collaborator especially during the 2 visits of the principle investigator.

In Israel, growing peaches and apples and producing off-season marketable fruit without exposure to winter chilling was demonstrated.Our work through this project improved our understanding of apples and peaches response to "Rest avoidance technique " to the extent of recommending it as a method of producing out-of-season fruits.This technique was adopted by a few commercial peach growers in the warm southern coastal plain of Israel. The Anna apple as well as other low-chilling requiring cultivars bred in Israel were shown to develop and fruit heavily using the rest avoidance method testifying to their special adaptation to tropical climate.

2. Research Objectives

The following were our research objectives:

1. To advance growing of deciduous fruit trees in tropical climate lacking winter chilling by using the rest-avoidance technique.
2. To determine quantitatively the various means and dosages needed to induce bud break.
3. To spread the knowledge of the use of rest avoidance in tropical countries.

3. Methods and Results

The collaborative work with the Kenyan researchers was based on two visits of the principle investigator to decide on the field trials to be set and performed. By touring the area two experimental plots were set: The first of bearing apple trees in a local growers' orchard and the second, to establish a new orchard of apples and peaches from selected rootstocks and cultivars. Also the specific treatments were decided upon. Data were collected from these two orchards.

In Israel, The AID project was based on detailed examination of the rest avoidance technique in peaches with regards to the effect of water withholding, rest breaking chemicals and defoliation on the response. This part was carried out as section of a MSc. Thesis. Also field examination on a semi commercial basis was carried out to examine the potential of the technique. In addition trials were carried out also with a few apple cultivars adapted to the technique. The trees were grown under a net cover in small containers and fertigated regularly. All treatments had at least 6 replicates of single trees and generally many more. Data were collected on the vegetative and reproductive performance and development of the trees and the fruits and were subjected to statistical analysis.In most cases the treatment reported were replicated over at least two years.

3.1. Visits to Kenya:

3.1.1.First visit Jan 6-17 1988. On initiation of the project, a visit of the principle investigator was taken place in order to start the work on the Kenyan part. The aim of this visit was to get a first hand information on the present situation of growing temperate zone fruits in Kenya, to plan the experimental treatments in existing orchards and to initiate a new

orchard to be grown and treated as planned from the very beginning of the project.
A suitable location in a grower's orchard was selected in Nyeri. The altitude was about 1800 m on a mild slope. Apple pear and peach trees for planting were sent from Israel in February 1988 and planted. A drip irrigation system based on filtration of river water was installed in the second year of the project. A delay in getting the funds in Kenya was due to the need to replace the Kenyan collaborator in the last minute.
Two other orchards were selected for chemical treatments. One of mostly the Anna cv. near Nairobi and the other of Anna and other apple cultivars in Machakos. The first one was kept in an exceptionally good condition. the following chemicals were sent from Israel for use in the experiments: Nerol 5 oil (product of Pazchem Israel), Mag for defoliation trials, (product of Palindent Israel) and Dormex (distributed by Agan Israel).

3.1.2.Second Visit to Kenya: June 1989. During this trip I toured the experimental plots that were established last year as well as discussed with the Kenyan colleagues the present and future situation of the project.

Rest breaking trials in Machakos.

Detailed report were presented by the Kenyan collaborators. I would like to relate my impressions regarding the treatments, the trees and the general setup of the experiments. This orchard is typical of the less advanced growers quite abundant in Kenya. The apple trees are surrounded by other crops including corn and banana plants. Intercropping is a system that is very difficult to change inspite of our efforts.
A number of cultivars were grown there. Anna showed in a few treatments very good response in budbreak and in one treatment also good level of fruit set and fruit development. The visit to the orchard was about 1 month prior to harvest.
Nutrient deficiencies were noted especially Zn. Recommendation for leaf analysis were given in order to improve tree nutrition. The competition with other interplanted crops could aggravate the deficiency problem.

Visit to the newly planted orchard in Nyeri

This orchard planted last year developed generally very good. Among the apples two cultivars

namely Anna and Grand (A cultivar popular in Israel of French origin) The two pears Spadona and White Gentile develop moderately while the peaches suffered heavily from flooded soil and water logging resulting in a high percentage of tree loss.
Suggestions for immediate treatments to break rest in the trees were given as well as instructions regarding the final installation of the drip irrigation system.
Suggestion as to adding a pollenizer for the Anna (Golden Dorset) was given.
Meteorological data collected on the site were found to be unreliable and a change of system was suggested.
Also training the trees was discussed and detailed pruning especially of the apples was suggested. The 1 year old apples had quite a few fruits testifying for the potential of production in this area.
In conclusion, we had two types of orchards in Kenya. One in a rural family holding that if management improves may serve as a model for development of apple production in such location. The other orchard is a typical large scale enterprise that may demonstrate the real potential of production in the Kenyan Highlands.

Apart from these orchards I had an opportunity to visit a few other privately owned apple orchards. One near Nairobi and the other in the Atti River area. The development of the trees, if the right cultivars and treatment is applied, is very striking. Still lack of knowhow is the critical factor in these orchards.

4. Experiments in Israel

4.1. Experiments with peaches

Trials with peaches grown in a meadow system in the Volcani Center Farm in Bet-Dagan, were used for the trials. Former results showed that rest avoidance is a possible approach for obtaining out-of-season fruit in the coastal plain in Israel (Erez A. 1987. Use of the rest-avoidance technique in peaches in Israel. Acta Hortic. 199:137-144). We dealt with various problems of development in trees treated with the rest avoidance technique.Poor leafing in winter time was reported in Acta Horticulture (see Appendix 1)
The following is a summary of other results that were published in Hebrew in Israel:

4.1.1. Trials in the meadow orchard in Bet-Dagan

Most of the work was conducted in the peach meadow orchard in Bet-Dagan with 9 year-old Earligrande on its own roots. The orchard was covered by a white hail net for protection. Irrigation to all the trees in trial was withheld during September and October. About 7 days prior to the chemical treatment (see below), irrigation was resumed followed the next day by spray of the defoliant "MAG" which consists of $Mg(ClO_3)_2$ at 0.36%. Two chemicals were tried: "Oil" was a combination of 4% narrow-range oil with a UR of 96% and 0.075% of Dinitro-ortho-cresol in a prepared emulsion. This treatment was preceded by 7% KNO_3. The other chemical tried was "Dormex" hydrogen cyanamide at 1.5%. A few different timing were tried: Early - spray of the chemicals in late October, Medium - spray in early November and Late - spray after mid November. Two pruning systems were tried: "cut" - the regular pruning of the mechanized meadow orchard system of heading back most of the tree top immediately after harvest in April. The other system designated as "Pole" was to leave the central branches and to trim the laterals to their bases.

Comparing the performance of two types of pruning systems in the meadow orchard and of two rest-breaking treatments revealed an advantage to the oil-DNOC-KNO_3 treatment over the cyanamide (Dormex) treatment and to the "pole" over the "cut" pruning systems (Fig 1).With the oil-pole combination a yield of close to 15 tones/hectare was obtained. The reasons for this advantage is the lack of damage to flower buds caused by this treatment as against the cyanamide treatment and the higher number of flower buds as well as the thicker branches in the "pole" system. Thicker branches could hold more reserves to support the autumn growth and fruit development .

The effects of both the pruning system and the rest-breaking treatment on yield was confirmed in 1988. Especially efficient was the early treatment (Late October) in this year (Fig 2).

The yield obtained and picked during March and Early April was typically consisting of smaller fruit than the regular one in the normal time of fruit ripening (Fig 3). In all treatments there was a trend of fruit size increase with the later harvests pointing to a possible influence of the new spring foliage. The control fruit reached a higher fruit weight due to fewer fruits on these trees in the later picking, stressing the Importance of spring foliage on fruit size. It has to be noted that winter foliage was very poor in the control trees. As against 61 to 63 g of

fruit weight, fruit ripening in May reached a weight of 95 to 100 g.

Following the effect of chemical and pruning treatments on fruit diameter in 1989 show an advantage to the earlier treatment where in both pruning systems over 40% of the fruit had a diameter of 55 mm or higher . " Poles" had over 85% of the fruit bigger or equal to 50 mm and over 15% of its fruit of a diameter of 60 mm.

Checking the total soluble sugars in the fruit shows (Fig 4) a gradual increase of TSS especially in the cyanamide (Dormex) treatment but also a small increase was noted with oil. The difference between the treatments seems to result from the difference in fruit load. The lower value for the control stems from the poor foliage cover during the winter. It has to be noted that the TSS value of the same cultivar in the normal time of fruit ripening is not higher than 9%.

The effect of the retainement of the 2nd crop in spring on the size of the winter fruit show a rather small although significant effect on fruit diameter (Fig 5). The extra load although small, is still having an important effect in reducing the already small out-of-season fruit and therefore should be avoided.

In conclusion, the meadow orchard pruning system , although adapted to out-of-season crop by allowing easy protection of the trees due to their small size, has a serious drawback namely thin framework branches that can not accumulate reserves as can the conventional tree. Leaving older framework wood in the "pole" system improved orchard performance. In combination with the oil treatment a considerable yield was shown to be obtained of mostly commercial fruit 60 to 30 days prior to the regular time of ripening of the Earligrande peach. Still there is place for improving the fruit size of this early crop.

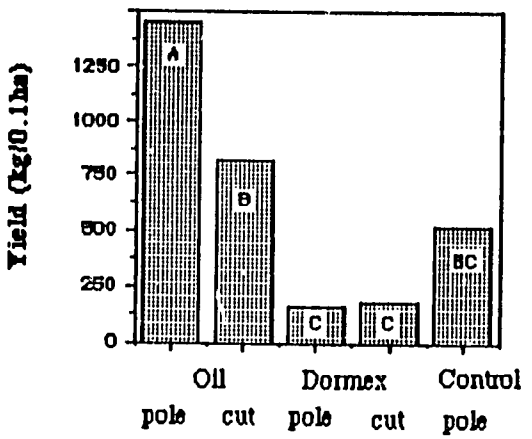

Fig. 1: Yield of 3rd term forcing treatment. Pick during 4/1987
(Mean separation by duncan's multiple range test, 5% level)

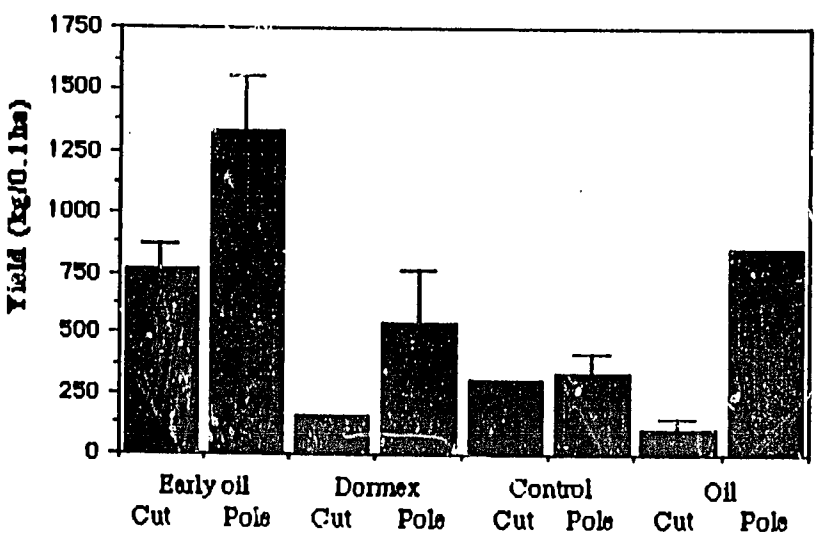

Fig 2: Effect of time and type of treatment, and pruning system on yield.
(When standard eror is not shown it is very small)

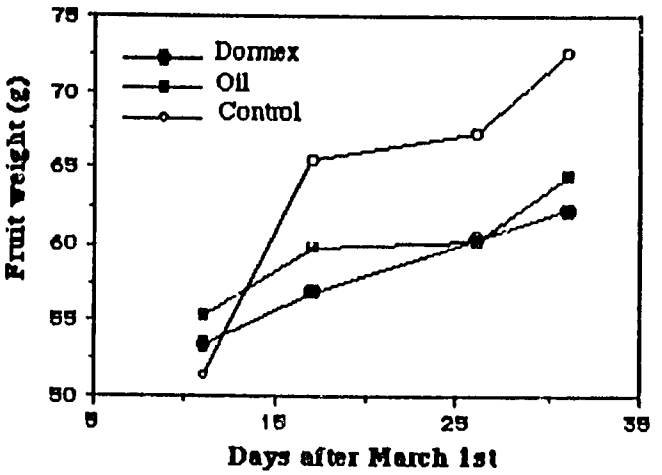

Fig.3: The effect of the rest breaking chemical on fruit weight in the Earligrande peach

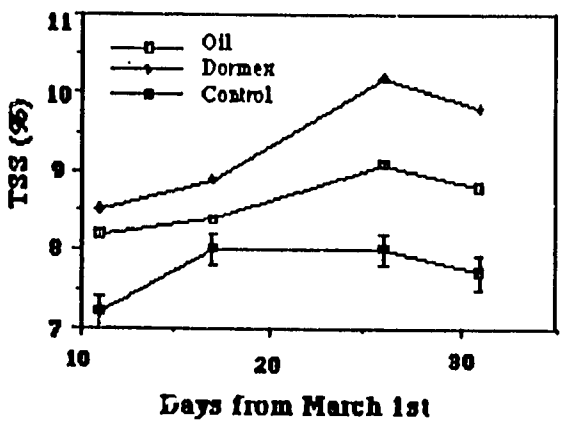

Fig. 4: The effect of rest breaking chemicals on fruit TSS % in Earligrande peach.

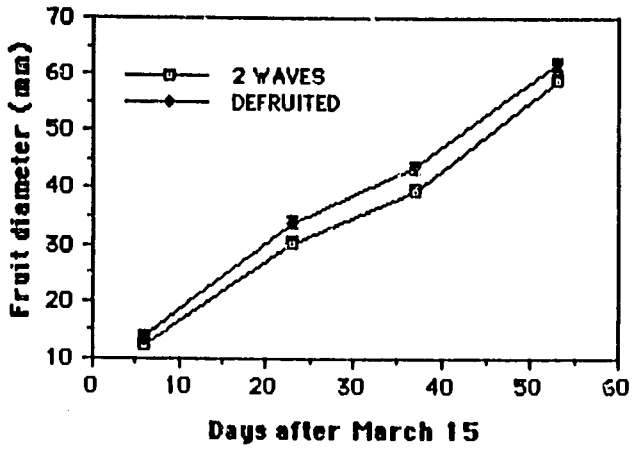

Fig.5: The effect of leaving or removing the second crop on fruit diameter increase of the first crop in Earligrande peach.

4.1.2. Field trials in the Southern Coastal Plain

The low level of precipitations and the rare events of hail in the "Bsor region" - the most precocious producer of early peaches- led us to try in a few commercial orchards the technique of rest avoidance. Three cultivars were tried: Earligrande, Flordaprince and Maravilha. Varied sensitivity among the cultivar to the defoliant was noted with Maravilha exhibiting a higher sensitivity. Damage to young twigs was obtained when $Mg(ClO_3)_2$ was applied at a high dosage. Dosages above 9 liters/ha of pure $Mg(ClO_3)_2$ caused damage, while dosages below 3 liters/ha did not defoliate the trees completely. Response in Maravilha was the worse among the three resulting from poor leafing in winter. Preliminary results point to the potential of this system in producing commercial crop 2 to 4 weeks earlier than the normal ripening date in this region.

The results of work conducted during 1988 in the Southern Coastal plain is reported below: It is a translation of a paper published in Hebrew in Alon Hanotea:

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Rest avoidance for early bud break and out-of-season fruit production in the Flordaprince peach

Erez, A., Yablowitz Z., and M. Frenkel

The aim of this work was to use the extreme early bud break possible by using rest-avoidance techniques to get bloom in December and fruit ripening in early spring.

Rest avoidance was found as a system operational in the tropics by a strong stimulus to the tree buds before entering into deep rest (2,5,7,8). Regularly, new and normal growth and fruiting is obtained and normal fruit develops. As against the tropics, in Israel a clear seasonality do exist and prior to the development of deep rest, in autumn, bud break is possible but under short days and cool weather. The familiar "Autumn bloom" that occurs in Israel in autumn in many deciduous fruit tree species results from conditions conducive to breaking of rest at a stage prior to the onset of deep rest. Normally, the combination of the following two agents are causing bud break: Early loss of leaves due to fungal infection or drought and a subsequent irrigation or early rains after a long desiccation period. At this stage flower buds are less dormant than vegetative buds resulting in bloom with scant foliage development.

In trial done in the experimental meadow orchard in Bet-Dagan it was found that the combination of summer desiccation followed by defoliation and rest breaking chemicals will cause a very strong bloom and leafing in low-chilling requiring peach cultivars. They will bloom in early December and ripen in March and April (4). Timing the treatment may affect the quality of the flowers and the ability to get good vegetative bud break. Advancing the treatment may cause the formation of incomplete flowers that can not set (1,4,6) while on the other hand allowed a better vegetative bud break. A delay in treatment led to a normal bloom but to a poor leaf cover as a result of entering of the vegetative buds to a deep dormant state (1,6). The developing fruit is exposed to the winter conditions that may, according to location, affect its development. It was found that the temperatures in the coastal plain of Israel allow normal fruit development (1,4,6). On the other hand, strong winds and hail may damage heavily the fruit if not protected by nets. In addition, there is an important role to the carbohydrates reserves in the tree brunches to support the fruit that develop during winter as the autumn foliage is too small to support all the carbohydrates needed by the developing

fruits.

This paper describes experiments done in 1988/89 in the Bsor region located in the southern coastal plain and excels in moderate winter temperatures. Preliminary experiments in this region were started already in 1986 and served as a basis for this trial.

Materials and Methods

As plant material served 6-year old Flordaprince trees in the Yesha settlement The plot was divided into 2 parts, the first was used to check different rest-breaking chemical treatment, and the second was a commercial plot using 2 rest breaking treatments. In the first part, 6 replicates with 2 trees /replicate were used. Irrigation was withheld towards the end of August and was renewed on October 18 1991. On October 20 1988, all treatments were sprayed (But for the early Cyanamide) with MAG 18 [$Mg(ClO_3)_2$] at 0.36 a.i. at 1000l/ha using a boom sprayer. Due to an insufficient defoliation, this treatment was repeated on October 30 at 2000 l/ha. Dormex [SKW of Germany producer (a.i. 50% hydrogen cyanamide)] applied early in the season at 1.5% and 2000l/ha on October 20 1988. On November 8 1988 the following treatments were applied with a gun sprayer at 2000 l/ha:

1. Dormex 1.5%
2. KNO_3 7% followed by Nerol 5 at 5% (contains 80% narrow-range-oil and 1.5% of DNOC).
3. Dormex 0.5% + KNO_3 7% followed by white oil at 5%.
4. Control (Only defoliation treatment).

On November 4 , the trees were moderately pruned. The defoliation treatment was very effective and the rest-breaking sprays were applied to fully defoliated trees. Bud break was determined as % of the buds that broke out of the total existing on premarked "standard branches" These branches were 35±5 cm length. On March 10 1989, scaffold girdling was performed on one of the pair trees. Harvest data were collected separately for every treatment and every picking. The following fruit characteristics were determined: Fruit weight, TSS using a table refractometer, firmness using a hand held penetrometer, fruit color by evaluation of red cover of fruit skin by quarters in a scale of 0 to 4, and rate of stone splitting in the fruit as %.

In parallel to the experimental orchard, a comparable trial was carried out in a commercial

orchard. The orchard was irrigated and defoliated by the same treatments as mentioned above. Two rest-breaking treatments were applied to an area of 0.15 ha each, on November 8 1988: 1. Dormex 1.5% and 2. KNO_3 7% followed by Nerol 5 at 5%.These treatments were applied by a commercial boom sprayer. The data collected were yield per tree, mean fruit weight and % of fruit with split pit.

Table 1: The effect of rest-breaking treatments on bud break in the Flordaprince peach

Treatment	% bud break ±S.E.
Control	22.0±5.0
Dormex 1.5% (Early, no Mag)	8.6±2.2
Dormex 1.5% (Late, After Mag)	86.3±4.6
KNO_3 7% followed by Nerol 5 5% (Late, After Mag)	88.7±3.9
Dormex 0.5% + KNO_3 7% followed by white oil 5% (Late, After Mag)	97.0±1.3

Table 2: The effect of rest-breaking treatments on yield and time of harvest in girdled and non-girdled trees in the Flordaprince peach

Treatment	Yield (Kg/tree)		% picking till April 7 1989	
	Girdled tree	non-girdled tree	Girdled tree	non-girdled tree
Control	36.5	23.0	17.0	5.6
Dormex 1.5% (Early)	19.8	13.3	7.6	3.0
Dormex 1.5% (Late)	35.4	26.7	25.1	18.0
KNO_3+Nerol 5	43.0	32.3	12.3	14.8
Dormex+KNO_3+ white oil	35.3	27.8	28.0	8.3

Table 3: The effect of rest-breaking treatments on fruit ch.. acteristics in the Flordaprince peach.

Treatment	Girdling	fruit color (0-4)	TSS (%)	Mean fruit Weight (g)	Split pit % Till April 10	Split pit % After April 10
Control	+	2.0	8.7	93.7	35	20
	-				28	16
Dormex 1.5% (Early)	+	1.8	9.5	94.8	30	16
	-	1.6	9.4	88.3	25	21
Dormex 1.5% (Late)	+	1.9	9.5	98.9	25	10
	-	2.1	9.5	83.2	39	26
KNO_3+Nerol 5	+	2.2	9.1	97.0	38	23
	-	2.3	8.8	87.8	27	21
Dormex+KNO_3+ white oil	+	1.8	9.7	98.7	34	16
	-	1.9	8.8	81.0	32	14

Table 4: Commercial treatments to break rest : Their effect on the yield and fruit characteristics in Flordaprince peach.

Treatment	Girdling	Yield/tree (Kg)	Early fruit (%)	Mean fruit Weight (g)	Split pit (%) Till April 10	Split pit (%) After April 10
Dormex 1.5%	+	33.1	36.0	98.9	33.1	26.2
	-	18.9	27.5	88.5	24.8	21.8
KNO3+Nerol 5	+	40.2	47.0	23.6	20.0	15.3
	-	29.7	32.4	87.8	23.3	16.9

Results and discussion

The level of bud break as checked on December 22 (Table 1) indicates a low efficiency to the

early spray with Dormex as a defoliant and rest breaking agent. The level of budbreak in the control show the response to defoliation alone. All the other 3 treatments exhibited a strong response. Especially strong was the effect of Dormex+KNO_3+ white oil. The late treatment with Dormex at 1.5% caused some terminal branch damage and a drop of flower buds throughout the canopy.

Picking started at the end of March and continued during most of April and the data summarized in Table 2. Large differences were found among the treatments on yield levels. Girdling as well seems to have an effect. The early Dormex treatment that had a poor effect on breaking buds, caused but a poor yield of the early crop. A second bloom occurred in late January of those that did not respond in autumn. The highest yield was obtained in the 0.5% Dormex+KNO_3+ white oil treatment. With regard to precocious maturation, the best treatments were Dormex+KNO_3+ white oil and late application of Dormex alone. Girdling increased the yield in all treatments (Table 2). This phenomenon result to our opinion from reduction in fruitlet drop in the girdled tree and from the larger fruits on these trees (Table 3). Girdling enhanced fruit ripening in all treatments but for Dormex+KNO_3+ white oil. This exception seems to result from the heavy fruit load on these trees.

Fruit quality was acceptable but split pit was severe especially in the first few pickings. In all treatments but for the late Dormex one, split pit was more severe in the girdled trees (Table 3). Examination of the yields in the commercial plot verified the girdling effect on increasing yield, fruit size and enhancing fruit maturation (Table 4). No effect was detected on the effect of girdling on increase in split pit. On the other hand, the abundance of split pits was more common in the earlier pickings resulting probably from incomplete development of the endocarp.

Conclusions

It was shown in this paper that under the winter climate of the Bsor area, out of season early peach crop (advanced ripening by 2-4 weeks) at 15 T/Ha is possible. This estimation is based on an average yield of 40 kg/tree and a density of 400 trees/Ha. Fruit quality was not satisfactory enough. The high levels of split pits indicate a problem with this particular cultivar. Evaluation of the response of other cultivars to this system revealed that Maravilha breaks vegetative buds poorly in response to the treatment and the low folinge cover is unable

to cope with the demand of the developing fruits (1).while Earligrande seems very adapted to the system (1,4,6).

Split pit phenomenon is a common feature of many precocious ripening peach cultivars and it stems from incomplete development of the stony endocarp while the pericarp reached maturity. It seems more obvious in large fruits but it definitely is affected by genetic factors. Winter growing conditions seems to strengthen this phenomenon. In the future, the sensitivity to split pit will have to be evaluated in new cultivars meant for the rest-avoidance technique besides the demands for low chilling requirements for vegetative and floral buds, adaptatior to develop under cool winters and high fruit quality.

4.2. Experiments with apples in Israel.

In October 1987 we have initiated a trial on the apple Anna in Kvutzat Shiler near Rehovot southern coastal plain. A group of 10 trees were sprayed on October 27 1987 with $Mg(ClO_3)_2$ at 0.54% and on November 3 1987 with KNO_3 7% followed by the oil-DNOC agent: Nerol 5 at 5%. or with H_2CN_2 as the agent Dormex at 2%. 4 adjacent trees of the pollenizer '28' were treated at the same time. A group of another 10 trees was left as untreated control. Evaluation of leaf drop revealed a complete effect with mild damage to the tips of young twigs. Both rest-breaking chemicals were very effective in inducing vegetative and floral bud break although the combination of KNO_3 7% followed by the oil-DNOC was superior to Dormex at 2%. Full and very heavy bloom was recorded on December 11 1987. No continuous extension growth was obtained as a terminal vegetative bud set after formation of 5 to 8 leaves. Nevertheless, this level of foliage was much better than that obtained with peaches. Resumption of growth occurred in late spring. The control trees retained their leaves through February and no bud break occurred before mid February. The bloom of the pollenizer trees was late compared to that of Anna with only a small overlapping. Very few fruits did set, probably due to this cause. Heavy damage to leaves resulting from infestation with mildew and scab was noted. It was thus concluded that in order to obtain a good bloom coincidence between Anna and its pollenizer the later has to be treated earlier with the defoliant and the rest breaking agent. furthermore, control of mildew and scab should be very rigorous during winter to secure the crop. A net protection over the orchard will

secure the yield from a possible hail damage.

Sixty trees of Anna grafted on Hashabi rootstock and 20 trees each of the following new low chilling varieties: 3-11, 60-A and 52-A all grafted on Hashabi were planted in February 1988 in 15 l containers filled with Volcanic tuff and peat moss at a ratio of 3:1 to be used for future trials. Development of the trees was very good in their first year.

In their second year, the trees were breaking rest well and produced a large amount of flower buds. on small spurs and on 1-year -old wood. in late October 1989 water was withheld for 3 days followed by defoliation with $Mg(Cl\ O_3)_2$ and latter with a combination of oil-DNOC and KNO_3. Bud break occurred in mid November and bloom in early December. Anna, and 3-11 were flowering profusely while 60-A and especially 52-A had fewer flowers. Vegetative growth was much poorer in 52-A than in the other cultivars. The best developing cv. vegetatively was Anna. A bee hive was introduced into the net-house resulting in a heavy fruitset. Fruit was developing normally although a few fruits were lop-sided due to an uneven seeds distribution.

Picking of apples started on May 7 1990 and finished a month later. Two thirds of the fruits in the 3-11 cv. and 80% in Anna were harvested by May 24 1990 with no clear effect of the rest breaking treatment. The treatment however did affect yield in 3-11 and fruit weight in 3-11 and Anna (Table 5). With 10,000 trees/ha, the crop obtained was between 14 to 22 t/ha in Anna and 3-11 respectfully. Fruit weight was rather small but quite commercial with Anna. Color and TSS were exceptionally good resulting from the cooler growing conditions. Anna entered a second bloom after harvest in early June. The flowers set fruit of a second crop that ripened by mid September. The fruit was of good eating quality but for its poor color (Table 5). Only a few fruits/tree did set yielding about 0.5 kg/tree.

Table 5: Fruit characteristics in apples treated by the rest-avoidance technique in 1990

Cultivar/treatment	Yield (kg/tree)	Fruit weight (g)	Fruit no. /tree	color (0-4)	TSS (%)
Anna +RBA*	1.43	93.4±1.7	15.31	1.72±0.13	11.5±0.2
Anna - RBA	1.38	84.8±2.3	16.27	1.86±0.14	12.7±0.2
3-11 + RBA	2.27	77.6±2.9	29.25	2.10±0.1	12.1±0.2
3-11 - RBA	0.53	61.9±3.6	8.56	2.20±0.2	12.6±0.3
Anna (2nd crop)		119.8±4.2		0.70±0.1	11.6±0.2

* RBA-Rest breaking agent: 5% oil-DNOC

The natural rosette of leaves formed from the mixed bud seems better adapted to the autumn fruit development than the peach with its simple leaf buds. No long growth was obtained till late in the season. No specific treatment was tried to promote such growth earlier.

In the 3rd year a repeated cycle was tried as in the second year. Level of bud break obtained was extremely high and uniform for Anna and 11-3, somewhat weaker in 52A and relatively poor in 60A. The relatively warm autumn in 1990 enhanced the early development of the vegetative and reproductive organs. Full bloom was obtained already in late November and first fruitlets were observed on December 10.

Table 6: Fruit characteristics in Anna apples treated by the rest-avoidance technique in 1991

Date	Yield /23 trees (Kg)	Fruit wt. (g)	color (0-> 4*)	TSS (%)	Firmness (Lbs)
April 11	10	73.0	1.5	9.9	18.9
April 21	16.5	65.6	2.1	9.8	17.7
April 29	25.2	84.9	2.2	11.6	15.8
May 16	12.5	68.8	1.8	11.9	15.0
Total/mean	**64.2**	**74.9**	**2.0**	**10.9**	**16.8**

*Evaluation as red cover of fruit surface in quarters.

An advancement of about 2 months was demonstrated with the out-of season Anna apples in

1991 (Table 6). The fruit was smaller than usual probably due to the low leaf area, but the quality was high with regards to the TSS and the total flavor. Color was relatively good for this cultivar. Yield of 2.8 Kg/tree was equivalent to 28 tons/Ha, lower than the regular crop in the conventional orchard in Israel but quite reasonable for the Tropics especially as there, two crops a year are expected.

5. Final conclusions

The objectives of the project were generally attained. Inspite of the difficulties in Kenya and the slow establishment of the experimental plots, it was shown that by use of rest avoidance very good budbreak is obtainable with the right cultivars and fruit production is possible.
It is a pity that collaboration with the Kenyan researchers was not strong thus hampering the advancement of the project to achieve its main goals in the tropical highlands. It seems that the knowhow developed through this project should be further spread among tropical countries facing problems of lack of chilling. This goal was achieved in part through reports in the International Symposium on "Temperate-Zone Fruits in the Tropics and Subtropics " held in Thailand in 1988 on part of the work of this project. Further reports will be delivered in the next meeting of this working group scheduled to meet in Alexandria Egypt in 1992. In Israel, we have shown that rest avoidance is a workable method that may be utilized commercially. Both peaches and apples (with certain low chilling requiring cultivars) were shown to bloom, set fruit and reach extremely early ripening. As against the tropics, in Israel at 32° N no long extention growth was obtained from autumn budbreak. The rosettes formed in both peaches and nectarines broke normally only after exposure to chilling in winter. Commercial fruit was obtained nevertheless by using this method when hail nets were used over the orchards.

Papers published supported by the AID project:

1. Erez A.and Lerner H.(1990) Means to improve leafing using rest-avoidance technique in peaches in Israel.. Acta Hort.279:239-246.
2. Erez A., Yablowitz Z. and Frenkel M. (1989). Rest avoidance for early bud break and out-of-season fruit production in the Flordaprince peach. Alon Hanotea 44: 989 - 992. (In

hebrew)

3. Lerner H., and Erez A. (1991). Advancing ripening of the Earligrande peach by rest avoidance. Hassadeh 71:881-887. (In hebrew).

6. Appendix 1: **Erez A.and Lerner H.(1989) Means to improve leafing using rest-avoidance technique in peaches in Israel.**

MEANS TO IMPROVE LEAFING OF PEACHES IN ISRAEL USING THE REST-AVOIDANCE TECHNIQUE

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Abstract

Under subtropical climates with mild winters and a relatively small difference in day length between summer and winter, entrance of fruit trees into a deep dormant state is more gradual than in the temperate zone and probably faster than in the tropics. Using defoliation at the proper time induces a generally good bud break of floral buds but relatively poor break of vegetative buds. By using rest-breaking chemicals we can improve considerably vegetative bud break but the growth obtained forms a rosette that is typified by the short internodes and by the formation of a resting terminal bud. The result is a normal development of the flower and fruit but a shortage of photosynthesizing leaf area to support the developing fruits leading to production of small fruit, poor in sugar and quality. The cause fo. the secondary domancy is a combination of the residual dormant state, the short days (down to 10.5 hrs) and the low temperatures in winter in Israel. In tropical areas, the constant daylength of about 12 hrs and the relatively warm conditions are enough to prevent the rosette formation in peaches. The shorter the daylength, the greater the risk of rosette formation.

In the present study an attempt was made to characterize the rosette formation and to improve the leaf area of trees forced to grow in autumn by chemical and physical means. The effect of artificial chilling was compared with defoliation followed by rest-breaking chemicals with and without exposure to long days. In addition, the effect of sprays with the growth regulators gibberellins and promalin on improving the vegetative growth was studied. We found that only when exposed to chilling could the tree fully overcome the rosette formation. Nevertheless, increase in day length as well as spray with both GA_3 and promalin increased the total leaf area produced.

Photosynthesis efficiency of autumn and spring leaves was studied as well as the relative importance of the three sources of carbohydrates for the fruits, namely: the reserves in the branches, autumn leaves and spring leaves. It was shown that autumn leaves are of prime importance to the fruit developing in winter and that their photosynthesis capacity is not inferior to that of spring leaves.

1. Introduction

It was reported that by using the rest avoidance technique, production of temperate-zone fruit in the tropics is possible (Erez and Lavi 1985, Edwards 1987, Edwards and Notodimedodio 1987). It has already shown that with the incorporation of three elements in combination, namely: a relatively long period of desiccation, defoliation and rest-

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breaking chemicals, good bud break also may be secured by the rest avoidance technique in subtropical climates (Erez 1987a). Foliage cover is the main limiting factor in producing a peach crop in winter under mild subtropical climates. It was shown that by using the rest avoidance technique if treatment is timed correctly (in Israel, defoliation around end of October), the flowers appearing are normal and fruit set is good and the fruit develops normally. Leaf buds, both terminal and laterals, break to a large extent but all form rosettes soon after appearing. This phenomenon testifies to the induction or rather persistence of dormancy in the growing tips that sets a terminal bud after development of a few leaves. The phenomenon of poor vegetative development was reported as one of the limiting factors of apple production in Indonesia (Verheij 1985). There lack of lateral vegetative bud break on shoots as well as failure of vegetative bud development from the spur limit the leaf area and causes an imbalance between the fruits of 'Rome Beauty' and the supporting leaves (Verheij 1985). In Israel, these rosettes break in early February, after being exposed to winter chilling in December and January. However, as fruit of the early cultivars matures in March, the photosynthates produced by the new flush can hardly support this fruit.

The questions which arose were:

1) Is the formation of the rosette due to the autumn climate of cool nights and moderate days with a short daylength of ca. 10.5-11 hours?

2) Can this phenomenon be overcome by different treatments?

3) What is the quantitative significance of the three possible sources of carbohydrates to the fruit: the reserves in the tree branches, the winter foliage and the spring foliage.

This paper reports on trials carried out during the last three years to answer these questions.

2. Materials and Methods

2.1. Potted trees

Potted peach trees were grown as described before (Erez 1988). When chilled artificially, the plants were exposed to continuous 6°C for 21 days. When left outdoors, the trees were sprayed with 0.36% of $Mg(ClO_4)_2$ (as the agent MAG, produced by Palindent Israel) which caused rapid defoliation (Erez 1985). For breaking rest the combination of KNO_3 at 7% followed by Oil-DNOC at 5% was sprayed after the leaves had dropped (Erez 1987a). For producing long day effect we added incandescent light at 17 $WM^{*}m^{-2}{*}Sec^{-1}$ flux density at mean plant height.

2.2. Meadow orchard trees

In the orchard trials, meadow orchard trees 8 to 9 years old of the cultivar 'Earligrande' were used. The trees were headed back every year after harvest (April) and the new growth developed produced the next years' crop. The following growth regulators were examined on both 'Earligrande' and 'Maravilha' peach cultivars: GA_3 and GA_{4+7}, both produced by Abbott Chemicals. Promalin (Abbott) containing 1.8% of GA_{4+7},

and of benzyladenine, and benzyladenine (Sigma). Whole small trees were sprayed with a small sprayer at a concentration of 100 or 400 mg/l a.i. There were 8 replicates per treatments with single tree replicates. The treatments were applied on December 15 (Winter application) and on January 4 (Early spring application). Level of bud break was followed and stage of growth evaluated in 6 grades as follows: 0 - No response; 1 - Green tip; 2 - Growth <1 cm;
3 - Growth >1 cm; 4 - Half-open leaf blade; 5 - Fully open leaf blade.

Leaf photosynthetic efficiency was determined with the aid of a portable Infrared Gas Analyzer Licor 6 000 (product of Licor Corporation, England), on fully developed leaves with a normal appearance; five replicates per treatment.

3. Results

3.1. Is the formation of the rosette due to the autumn climate?

An experiment was set up to compare the effects of chilling, change in day length with control. 'Earligrande' potted peach trees were exposed to one of the following three conditions:

1) Defoliated with $Mg(ClO_4)_2$ and sprayed with oil-DNOC and left under natural conditions during November and December in Bet Dagan.

2) As in 1. but exposed to a longer photoperiod of 18 hrs obtained by added incandescent light from half an hour before sundown until midnight.

3) On October 7th, potted trees were transferred to a refrigerated cooler at 6°C in 6 hr photoperiod for 21 days. Later the trees were exposed to the natural conditions at Bet Dagan. The behavior of the trees was entirely different in the 3 treatments. The chilled trees grew vigorously in spite of the cool weather and the short days while the two other non-chilled treatments rosetted shortly after budbreak. There was a considerable increase due to daylength in level of budbreak and in leaf size (Table 1). Fruit total soluble solids did not differ in the two nonchilled treatments, but in both it was higher than in the chilled treatment (Table 1). This was probably due to the competition between fruit development and vegetative growth. Fruit color was inferior in the chilled treatment, due to shading.

3.2. Can the rosette formation be overcome by different treatments?

Application of promalin or gibberellic acid to 'Maravilha' peaches induced to break in autumn but which did not break vegetative buds, showed (Figure 1) that promalin at 100 and 400 mg/l and gibberellic acid at 400 mg/l did advance vegetative budbreak considerably.

Another typical effect of these growth regulators was advancement of the spring flush. Treatment on January 4 advanced very markedly spring growth (Table 2), leading to a better utilization of the newly formed foliage by the existing and developing fruit.

Another possibility for improving the production potential of the

winter foliage was to improve their efficiency. For this purpose, treatments with promalin, benzyladenine GA_3 and GA_{4+7} were tried. Photosynthesis was determined on a clear day in December (Figure 2).

Promalin containing benzyladenine, and benzyladenine alone were shown to improve photosynthetic efficiency as compared with the non-treated control. The two gibberellins did not differ in their fixation of carbon from the control. GA_{4+7} produced pale chlorotic leaves as compared with GA_3 which produced normal green leaves.

3.3. What is the quantitative share of all possible sources?

The effect of the relative contribution of the three sources for photosynthates supply to the developing fruits was investigated in the 'Earligrande' peach trees treated as follows:

1) Trees were defoliated and sprayed with 5% oil with no DNOC. They produced only flowers and no vegetative growth. Spring vegetative growth which started in early February was left on the trees.

2) As in 1 but the spring vegetative growth was tipped off when it appeared.

3) Trees were defoliated and sprayed with 5% oil and DNOC, bloomed, and grew vegetatively with abundant winter foliage of rosettes. Spring vegetative growth which started in early February was left on the trees.

4) As in 3 but the spring vegetative growth was tipped off when it appeared. This set up produced four combinations of sources: Reserves in the branches only (Treat. 2); branches and spring foliage (Treat. 1); branches and winter foliage (Treat. 4); and branches and winter and spring foliage (Treat. 3). Fruit size, fruit weight fruit color and TSS were all better when winter foliage was present. Spring foliage did not have a marked effect on fruit characteristics (Table 3).

4. Discussion

From a comparison of chilled and nonchilled peach trees it was demonstrated that the restricted vegetative growth obtained in winter in the coastal plain of Israel is not caused by the prevailing climatic conditions since when chilled, tree growth continued uninterrupted. The cause for the rosette formation is thus due to a secondary dormant state induced in the terminal bud. By increaseing the photoperiod leaf area per plant was increased by an increase in percent budbreak individual leaf area and number of leaves per sprouting bud.

Growth regulators were found to improve leaf area by advancing the break of the terminal bud in the rosette and thus obtaining an earlier foliage cover in spring. Source efficiency was improved by promalin, which increased photosynthetic efficiency. This effect was due to the benzyladenine as shown when the constituents of promalin were checked individually. This effect of cytokinins on photosynthetic activity agrees with that reported in the literature (Kulaeva 1979, Partier et al., 1982).

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Evaluation of the relative importance of the various sources supporting the developing fruit, emphasized the importance of the reserves in the branches and the contribution of the winter foliage. Spring foliage seems to contribute very little to the almost fully mature fruit. The conclusion drawn from this work is that we should make special efforts to build a high level of tree reserves in autumn and to improve winter foliage.

Acknowledgements

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References

Edwards, G.R., 1987. Producing temperate-zone fruit at low latitudes: Avoiding rest and the chilling requirement HortScience 22:1236-1240.

Edwards, G.R., and Notodimedjo, S., 1987 Defoliation, bending and tip pruning of apple under tropical conditions. Acta Hort. 199:125-127.

Erez, A., 1982. Peach meadow orchard: Two feasible systems. HortScience 17:138-142.

Erez, A., 1985. Defoliation of deciduous fruit trees with magnesium chlorate and cyanamide. HortScience 20:452-453.

Erez, A., 1987a. Use of the rest avoidance technique in peaches in Israel. Acta Hort. 199:137-144.

Erez, A., 1987b. Chemical control of budbreak. HortScience 22:1240-1243.

Erez, A., and Lavi, B., 1985. Breaking bud rest of several deciduous fruit tree species in the Kenyan highlands. Acta Hort. 158:239-248.

Kulaeva, O.N., 1979. Cytokinin activity in plants. in:Skoog F. (Ed.) Plant Growth Substances Springer Verlag Berlin.

Partier, B., Lehmann, J., Lerbs, S., Lerbs, W., and Vollgien, R., 1982. Cytokinin control in the synthesis of plastid proteins: Rubisco. in: Wareing P.F. (Ed.) Plant Growth Substances. Academic Press N.Y.

Verheij, E.W.M., 1985. Apple growing in East Java: The scope for improvements. Acta Hort. 158:47-52.

Table 1 - The effect of chilling and photoperiod on foliage development and fruit characteristics in 'Earligrande' peach trees grown in Bet Dagan, Israel.

Treatment	Veg.budbreak (/10 branches)	Leaves/bud (No.)	Leaf area (cm^2)	Fruit color (0-4)	Fruit TSS (%)
Control outdoors	35	3.6±1.7	8.8±1.0	4	7.9±0.2
Long day outdoors	67	3.5±0.2	16.6±0.8	4	8.1±0.2
Artificial chilling	170	4.3±0.2*	17.1±3.4	2	6.3±0.6

* Checked on Dec. 16.

Table 2 - The effect of late winter application of promalin and gibberellic acid on budbreak of the spring flush in 'Maravilha' peach trees.

Treatment (mg/l)	Vegetative development (0-5*)	
Control	0.0	C
Ga, 100	2.6	B
Ga, 400	4.3	AB
Promalin 100	2.7	B
Promalin 400	4.9	A

* Evaluation in 6 grades: 0 - No responses; 1 - Green tip; 2 - Growth <1 cm; 3 - Growth >1 cm; 4 - Half-open leaf blade; 5 - Fully open leaf blade.

Table 3 - The effect of the different sources of supply for winter-grown fruit of the 'Earligrande' peach on its fruit characteristics.

Source	Color (0-4)	Diameter (mm)	Weight (g)	TSS (%)	Acids (meq./g f.wt)
Branches	3.0±.2	47.2±0.9	54.1±6.2	6.1±.6	1.4±0.1
Branches+WF*	4.0±.2	53.0±4.3	68.9±4.4	7.7±.2	1.2±0.1
Branches+SF*	3.0±.1	48.1±1.1	61.4±2.5	6.4±.4	1.3±0.1
Branches+WF+SF*	3.6±.1	52.8±1.7	68.4±4.3	7.7±.5	1.4±0.2

* WF - Winter foliage; SF - Spring foliage.

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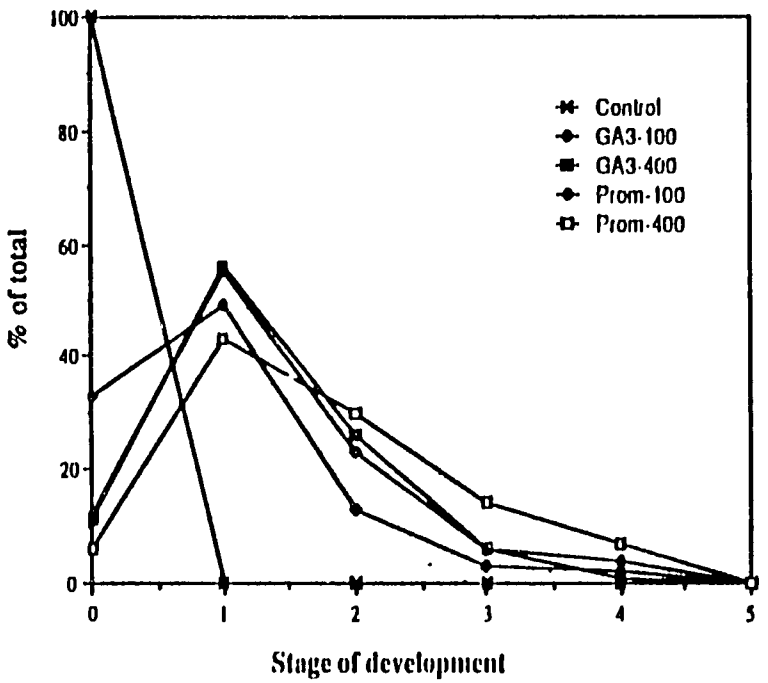

*Evaluation on 6 grades: 0=No response; 1=Green tip; 2=Growth <1 cm; 3=Growth>1 cm; 4= Half-open leaf blade; 5= Fully open leaf blade.

Fig 1: The effect of early winter application of Promalin and gibberellic acid on budbreak of the spring flush in 'Maravilha' peach trees. (Evaluated on 6 grades*)

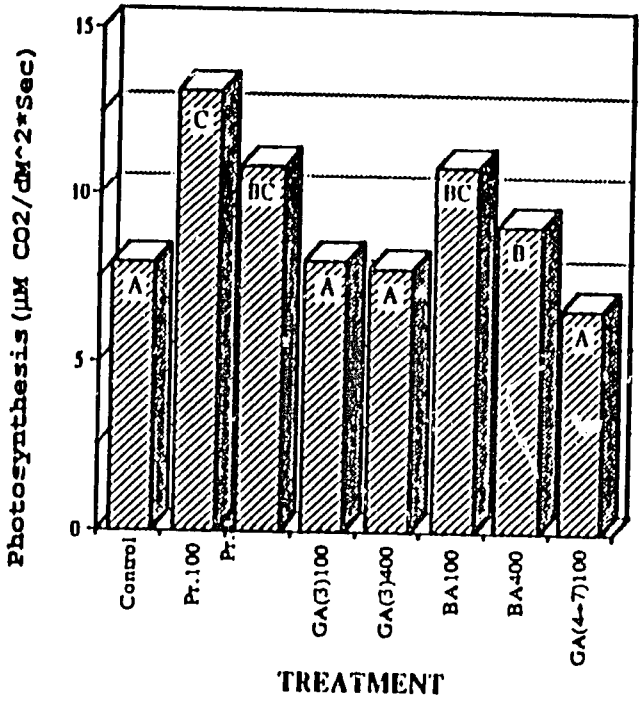

Fig. 2: The effect of Promalin (Pr), gibberellins and benzyladenine (BA) on photosynthesis activity of cv. 'Earligrande' peach winter leaves. Growth regulator concentration is shown in mg/l. The leaves were treated on December 15 and the measurements were carried out on mid January on a clear day.