

Effect of nitrogen, phosphorus, potassium fertilisation and manure on fruit yield and fruit quality of the peach cultivars ‘Spring Time’ and ‘Red Haven’

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Abstract. The objective of the present research was to study the response of the peach cultivars ‘Spring Time’ and ‘Red Haven’ to nitrogen, phosphorus, potassium fertilisation and manure. The following fertiliser combinations were used: control (no fertilisation), N, P, K, NP, NK, PK, NPK, cattle manure, N+manure, P+manure, K+manure, NP+manure, NK+manure, PK+manure, NPK+manure. The research was conducted during a period of 10 years (from the 5th to the 14th year of the productive life of the peach trees). Application of N plus manure to peach trees of the cv. ‘Spring Time’ resulted in the highest fruit yield. Total soluble solids content (%) of fruits of the cv. ‘Spring Time’ did not significantly alter in comparison to the control for all the fertiliser combinations used. The lowest yield of trees of the cv. ‘Red Haven’ was recorded in the treatments P, PK, and the control. The highest percentage of split pits of fruits of the cv. ‘Red Haven’ was recorded in the control, while the lowest in the NK, and PK+manure treatment in comparison to all the others. The highest percentage of incomplete fertilised fruits was recorded in the PK and manure treatments in comparison to all the others. Trees of the cv. ‘Red Haven’ fertilised with P, K, and PK begun to produce diminished yields from the 11th year. For both cvs., at the age of 15, trees fertilised with P, K, PK and the control had finished their economic cycle as yield decreased to very low levels.

Key words: fruit firmness, peach fertilisation, peach fruit yield, total soluble solids content, split pits

INTRODUCTION

Peach trees are cultivated in large areas in certain regions of northern Greece. On fertile soils, N is often the only nutrient that needs to be supplied to peach trees on a regular basis. On less fertile soils, deficiencies of K, Mg, Mn, Fe, Zn and B may develop. Deficiencies of P, Ca, S and Cu are rarely seen (Johnson & Uriu, 1989; Johnson, 1993). A nutrient survey in Greece indicated that zinc, manganese and iron deficiencies are frequent in peach orchards (Stylianidis & Syrgiannidis, 1995). Several reports have shown that increases in fruit set of cherries (White, 1968) and apricots (Jackson, 1970) can be obtained by N fertilisation. ‘Jonathan’ apple trees deficient in P showed a retarded development with a reduced number of floral meristems (Taylor & Goubran, 1975). In peach, P applications have increased flower formation, whereas N was found to reduce it (Fukuda & Kondo, 1957). Yield and fruit weight of peach fruits increased with increasing the rate of application to up to 700 g K tree⁻¹ (Awasthi et al.,

1998). Saenz et al. (1997) proposed that N-stimulated increases in peach yields are associated with extended fruit development period and increased fruit sink capacity. Arora et al. (1999) concluded that flowering intensity, fruit set, fruit weight and fruit yield were directly associated with leaf N content. Mineral nutrition is a pre-harvest factor that affects fruit quality and has to be performed very carefully since, after harvest, peach quality cannot be improved but only maintained, (Crisosto et al., 1997).

The aim of the present research was to study the response of the peach cultivars ‘Spring Time’ and ‘Red Haven’ to nitrogen, phosphorus and potassium fertilisers, manure, as well as some combinations of these. Because fertilisation of peach trees exerts a significant role on fruit yield as well as on fruit quality, the following measurements were accomplished: fruit yield; total soluble solids content; flesh firmness; split pits and incomplete fertilised fruits.

MATERIALS AND METHODS

The research was conducted during a period of 10 years (from the 5th to the 14th year of the productive life of the trees) in a peach (*Prunus persica* L. Batsch) orchard, on a farm of the Pomology Institute (Skydra area). The experimental trees of the cvs. ‘Spring Time’ (early season) and ‘Red Haven’ (mid season) were grafted on wild seedlings, planted at distances of 5x5 m and trained in a typical vase shape. The soil of the orchard was characterised by clay loam. The soil properties of the experimental orchard are presented in Table 1. The soil samples were air dried, crushed to pass a 2-mm screen and analysed for pH in a 1:1 soil to water ratio, electrical conductivity in a 1:5 soil to water extract, texture (hydrometer method), CaCO₃ with a volumetric calcimeter and organic matter content after wet oxidation (Page et al., 1982).

Table 1. Soil properties of the experimental orchard from a depth of 30–70 cm.

Soil property	
Texture class	CL (Clay loam)
pH (1:1 H ₂ O)	7.35
CaCO ₃ (%)	1.22
Organic matter (%)	0.59
Electrical conductivity (1:5) (mS cm ⁻¹)	0.96

From the planting of the trees up to the 7th year, nitrogen was applied at half amount as ammonium sulphate and half amount as ammonium nitrate. Starting from the 8th year and on, nitrogen was applied only in the form of ammonium sulphate. Ammonium sulphate was applied 40 days before bloom and ammonium nitrate 2 times after leaf emergence. Phosphorus was applied until the 7th year in the form of 0-46-0 and, for the rest of the years, in the form of 0-21-0. Potassium was applied in the form of 0-0-50. Phosphorus and potassium fertilisers as well as manure were applied at the beginning of winter. The following fertiliser combinations were used: control (no fertilisation), N, P, K, NP, NK, PK, NPK, cattle manure, N + manure, P + manure, K +

manure, NP + manure, NK + manure, PK + manure, NPK + manure. The amount of fertilisers that were applied each year has been presented in Table 2.

Fertiliser applications until the 5th year were performed at the projection of the foliage of the trees, and at the whole surface of the experimental blocks during the rest of the years. In order to avoid nutrient deficiencies of the rest nutrients, the following treatments were performed every 2 years. Boron was applied to the soil in the form of ‘Solubor’ (20.5% B) at a quantity of 60 g tree⁻¹. Zinc was provided as ZnSO₄ by spraying the trees during winter (0.25 %). Manganese was provided as MnSO₄ by spraying the trees during winter (3%). Magnesium was provided as MgSO₄·7 H₂O by spraying the trees a month later after full bloom (1%). Iron was applied as ‘Sequestrene 330’ (10% Fe) at a quantity of 30 g tree⁻¹.

The following measurements were performed: a) fruit yield (kg tree⁻¹). Yields were yearly recorded and data presented are the means of 10 years, from the 5th to the 14th year of the productive life of the trees. b) Total soluble solids content (%) was determined with an Atago PR-1 electronic refractometer. c) Flesh firmness (kg cm⁻²) was measured with an Effegi penetrometer (8 mm plunger). Total soluble solids content and flesh firmness were measured, over a period of 10 years, in fruit samples consisting of 10 fruits per tree at harvest. d) Split pits (%), and e) incomplete fertilised fruits (%) were measured, over a period of 10 years, in fruit samples consisting of 50 fruits per tree at harvest.

The adopted experimental design was a randomised complete block with 5 replications of 16 treatments (fertiliser combinations) per cultivar. Differences between means were evaluated using Duncan’s multiple range test at *P* = 0.05.

Table 2. Amount of fertilisers applied to the trees from the first year until the fourteenth for the cvs. ‘Spring Time’ and ‘Red Haven’.

Age of the trees	N (g tree ⁻¹)	P ₂ O ₅ (g tree ⁻¹)	K ₂ O (g tree ⁻¹)	Manure (kg tree ⁻¹)
1	38	38	38	12
2	76	76	76	24
3	114	114	114	36
4	152	152	152	48
5	190	190	190	60
6	456	228	228	72
7	532	266	266	84
8–14	608	304	304	100

RESULTS AND DISCUSSION

Application of N plus manure to peach trees of the cv. 'Spring Time' resulted in the highest yield of the trees (Table 3). On the contrary, control, P, K, and PK fertilisation resulted in very low yields. Application of manure significantly increased yield in comparison to the treatments containing the nutrient elements N, P, and K in the form of fertilisers previously reported. All fertiliser treatments (except PK) significantly increased yield in comparison to the control. A higher yield of trees of the cv. 'Red Haven' was recorded in the treatments with N and NPK but it was not significantly different from those of NP, NK, manure, PK+manure, and NPK+manure (Table 4). The lowest yield was recorded in the treatments with P, PK and control. Application of manure with P, K and PK significantly increased yield in comparison to the treatments containing the previous nutrient elements in the form of fertilisers previously reported. Nitrogen deficiency leads to small fruit with poor flavour and unproductive trees (Crisosto et al., 1997). In plants suffering from N deficiency, reduction in net photosynthesis and decline of growth of leaves is observed (Marschner, 1995).

Nitrogen has the greatest effect of all nutrients on fruit quality. Rader et al. (1985) have pointed out that N fertilisation results in an increase of peach size. Nitrogen fertilisation stimulates peach yield by increasing the period for fruits to use assimilates (Saenz et al., 1997). Peach pure from trees fertilised with 45 kg N ha⁻¹ at budbreak had the best overall sensory quality (Olienyk et al., 1997). The effect of mineral nutrition in the process of fruit setting is well documented. Increases in fruit set can be obtained by N fertilisation, while P application enhanced bud burst (Khan et al., 2000). Ballinger et al. (1966) reported that P appeared to have only a little beneficial effect on peach yield. Application of up to 0.7 kg of K₂O peach tree⁻¹ resulted in an increase in yield, fruit weight and fruit quality (Cummings, 1973). Peaches grown under Californian conditions should be kept between 2.6 and 3% dry mass leaf N for best fruit quality (high red colour development and maximum storage performance) (Crisosto et al., 1997).

Total soluble solids content (%) of fruits of the cvs. 'Spring Time' and 'Red Haven' did not alter significantly in comparison to the control for all the fertiliser combinations used (Tables 3 & 4). Stylianidis and Syrgiannidis (1995) reported that fruit soluble solids content (%) of peach trees did not show significant correlation with any nutrient element. However, in apricots, Bussi et al. (2003) reported that increased K fertilisation enhanced fruit soluble solids and colouring. Firmness of fruits of the cv. 'Spring Time' was higher in the following treatments: NP, NK, NK + manure, NPK + manure (Table 3). Firmness of fruits of the cv. 'Red Haven' was highest in the NK treatment and lowest in the K one (Table 4). Ballinger et al. (1966) reported that K fertilisation had little or no effect on firmness, storage quality and acidity of peaches. Raese (1998) indicated that fruit firmness of fruits on apple trees receiving calcium nitrate fertiliser was greater than the firmness of those fertilised with ammonium sulphate, 17-17-17 and mono-ammonium sulphate. Application of fertilisers with a high N content reduced the fruit firmness of the Zacatecas-type peach (Hernandez-Fuentes et al., 2002).

Table 3. Effect of N, P, K fertilisers and manure on yield, total soluble solids content, fruit firmness and incomplete fertilised fruit of the peach cv. 'Spring Time' during a period of 10 years.

Fertilisation	Yield (kg tree ⁻¹)	Total soluble solids content (%)	Fruit firmness (kg cm ⁻²)	Incomplete fertilised fruits (%)
Control	46 h*	10.13 a	8.28 def	30.0 ab
N	107 a	10.48 a	8.31 def	25.0 cde
P	72 fg	10.24 a	7.50 f	31.0 a
K	63 g	10.21 a	7.46 f	28.3 abc
NP	91cde	10.40 a	9.62 ab	30.3 ab
NK	83 de	10.68 a	9.89 a	27.0 abcde
PK	51 h	10.44 a	8.07 def	31.0 a
NPK	84 de	10.32 a	8.69 bcde	30.3 ab
Manure	80 ef	10.26 a	7.71 ef	26.0 bcde
N + Manure	109 a	10.07 a	8.69 bcde	23.0 de
P + Manure	94 bcd	9.84 a	8.57 bcdef	24.8 cde
K + Manure	86 de	9.85 a	8.18 def	27.5 abcd
NP + Manure	103 ab	9.96 a	8.47 cdef	17.3 f
NK + Manure	105 ab	10.05 a	8.93 abcd	23.3 de
PK + Manure	99 abc	9.95 a	7.93 def	22.5 e
NPK + Manure	93 bcd	9.96 a	9.42 abc	24.3 cde

*Means followed by the same letter in the same column are not significantly different (Duncan's multiple range test, $P = 0.05$)

Table 4. Effect of N, P, K fertilisers and manure on yield, total soluble solids content, fruit firmness, split pits and incomplete fertilised fruits of the peach cv. 'Red Haven' during a period of 10 years.

*Means followed by the same letter in the same column are not significantly different (Duncan's multiple range test, $P = 0.05$)

Fertilisation	Yield (kg tree ⁻¹)	Total soluble solids content (%)	Fruit firmness (kg cm ⁻²)	Split pits (%)	Incomplete fertilised fruits (%)
Control	76 h*	9.55 a	10.41 abc	16.5 a	31.8 de
N	159 a	9.61 a	11.08 ab	12.9 cde	35.5 c
P	82 h	9.56 a	9.73 bc	14.1 bcd	36.3 bc
K	104 fg	9.72 a	9.19 c	11.8 de	31.3 ef
NP	155 ab	9.96 a	11.90 ab	12.3 de	27.8 fgh
NK	149 abc	9.93 a	12.26 a	8.1 g	34.8 cd
PK	91 gh	9.77 a	10.66 ab	11.2 ef	40.0 a
NPK	158 a	9.65 a	11.55 abc	15.7 ab	30.5 efg
Manure	137 abcd	9.84 a	10.70 ab	11.1 ef	39.5 ab
N + Manure	130 bcde	9.27 a	11.59 ab	15.5 ab	27.0 gh
P + Manure	129 cdef	9.31 a	11.10 ab	12.1 de	30.8 ef
K + Manure	117 def	9.40 a	11.15 ab	14.9 abc	26.0 h
NP + Manure	112 efg	9.52 a	11.65 ab	12.2 de	26.5 h
NK + Manure	105 fg	9.17 a	11.28 ab	9.5 fg	28.3 efg
PK + Manure	139 abcd	9.38 a	10.80 abc	8.7 g	27.8 fgh
NPK + Manure	136 abcde	9.16 a	11.10 ab	12.7 de	30.3 efg

The lowest percentage of incomplete fertilised fruits of the cv. 'Spring Time' was measured in the NP + manure treatment, while higher at the following treatments: control, P, K, NP, NK, PK, NPK, and K + manure (Table 3). The highest percentage of incomplete fertilised fruits of the cv. 'Red Haven' was recorded in the PK and manure treatments in comparison to all the others (Table 4). However, the lowest percentage of incomplete fertilised fruits was recorded in the K + manure treatment, although it was not significantly different from NP, N + manure, NP + manure, NK + manure, and PK + manure treatments. Fruit drop during the growing season is usually associated with the percentage of incomplete fertilised fruits. Potassium fertilisation was found to decrease fruit drop of canning peach cultivars (Stylianidis & Syrgiannidis, 1995). The results of our study indicate that tree nutrition is a factor that affects the percentage of incomplete fertilised fruits. Furthermore, it can be concluded that the two cvs. responded differently to the fertiliser applications and the percentage of incomplete fertilised fruits is cultivar dependent.

The highest percentage of split pits of fruits of the cv. 'Red Haven' was recorded in the control followed by NPK, N + manure, and K + manure treatments. The lowest percentage of split pits was measured in the NK and PK+manure treatment, although not significantly different from the NK + manure (Table 4). Fruits with split pits are generally misshaped and frequently open at the stem end, which allows the entry of insects and diseases. The pits of these fruits are broken in several places and the cavity may contain a gummy substance. Early-ripening peach cultivars exhibit this problem in a higher degree than the mid-season, and any practice or weather condition that reduces fruit set and encourages large fruit size may accentuate the occurrence of split or shattered pits. These practices would include excessive fruit thinning and girdling, heavy irrigations or high nitrogen application close to harvest (Ryugo, 1988; O' Malley & Proctor, 2002). The results of our study indicate that appropriate fertiliser application may reduce the percentage of split pits of peach fruits. The reduction of the percentage of fruits with split pits is of high economic importance for canning industry.

Trees of the cv. 'Spring Time' that were not fertilised began to produce diminished yields from the 8th year from their planting and further. Trees fertilised with P, K, and PK began to produce diminished yields from the 10th year. At the age of 15, trees fertilised with P, K, PK and the control had finished their economic cycle as yield decreased to very low levels. On the contrary, trees in all the other treatments until the 14th year that the measurements were completed produced sufficient yields. Unfertilised trees of the cv. 'Red Haven' began to produce diminished yields from the 9th year from their planting and further. Trees that were fertilised with P, K, and PK began to produce diminished yields from the 11th year. At the age of 15, trees fertilised with P, K, PK and the control had finished their economic cycle. On the contrary, trees in all the other treatments until the 14th year that the measurements were completed produced sufficient yields.

CONCLUSIONS

Nitrogen, P, K fertilisation and manure exerted a significant role on fruit yield and quality of the peach cvs. 'Spring Time' and 'Red Haven'. Application of N plus manure to peach trees of the cv. 'Spring Time' resulted in the highest fruit yield. Total soluble solids content (%) of fruits of the cv. 'Spring Time' did not significantly alter

in comparison to the control for all the fertiliser combinations used. At the age of 15, peach trees fertilised with P, K, PK and the control had finished their economic cycle as yield decreased to very low levels. The smallest fruit yield of trees of the cv. 'Red Haven' was recorded in the treatments with P, PK, and the control. The highest percentage of fruits with split pits was recorded in the control while the lowest in the NK and PK+manure, in comparison to all the other treatments. The highest percentage of incomplete fertilised fruits was recorded in the PK and manure treatments in comparison to all the others. It was concluded that the two peach cvs. did not respond in the same way to the various fertiliser combinations, indicating a genotypic effect.

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