STUDIES ON THE EFFECT OF N, P AND K FERTILIZER LEVELS ON GROWTH, YIELD AND QUALITY OF KIWIFRUIT CV. ALLISON

Thesis

by

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COLLEGE OF HORTICULTURE
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2004

Affectionately Dedicated

to

Anu, Nishu & Abbu

Dr. J.S. Chandel
Scientist

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CERTIFICATE-I

This is to certify that the thesis entitled **"Studies on the effect of N, P and K fertilizer levels on growth, yield and quality of kiwifruit cv. Allison"**, submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (Pomology)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. Sanjay Kumar (H-2001-50-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place : **Nauni, Solan**
Dated : 9 **January, 2004**

8/1/2004

(J.S. Chandel)
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled **"Studies on the effect of N, P and K fertilizer levels on growth, yield and quality of kiwifruit cv. Allison"**, submitted by **Mr. Sanjay Kumar (H-2001-50-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (Pomology)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

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(*Sanjay Kumar*)

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INTRODUCTION

The kiwifruit (*Actinidia deliciosa* Chev.) a member of family Actinidiaceae is the most recent fruit crop grown and marketed successfully in the world. Presently, it occupies an area of 60,098 ha with the total production of 1,001,121 MT (FAO, 2002) in the world. Although, this fruit originated in China, yet its full economic potential was exploited by the New Zealanders. New Zealand accounts for over 70 per cent of world trade and exports its produce to more than thirty countries (Franco, 1990). In other countries of the world, its cultivation gained momentum after 1960. Now the fruit is being cultivated on large scale in Italy, China, USA, Japan, France, Belgium, Germany, South Africa and Australia.

In India, kiwifruit was first introduced in 1960's at Bangalore, however, it could not be grown successfully for the lack of chilling requirement to overcome dormancy. Later on, in 1963 it was introduced in Shimla Hills of Himachal Pradesh (Dadlani *et al.*, 1971). After evaluation in different agroclimatic conditions, this fruit was recommended for commercial cultivation in the mid hills (900-1800 m amsl) of the state. It can also be grown in mid hills of Jammu and Kashmir, Uttaranchal, Arunachal Pradesh, Sikkim, Meghalaya and Nagaland.

The fruit has a refreshing delicate flavour, pleasing aroma and high nutritive value. It is rich in vitamin C, carbohydrates and posseses sufficient quantity of vitamin A, B and niacin (Ben-Arie *et al.*, 1982).

Mineral nutrition plays an important role in growth, development and yield of kiwifruit vines (Ferguson and Eiseman, 1983). In order to ensure a good fruit production, application of manures and fertilizers is a common orcharding practice. The heavy production of fruits year after year depletes the soil nutrient element reserves, thus necessitates nutrient elements application every year in order to have an economic fruit production and also to maintain soil fertility at a desirable level. Nitrogen, phosphorus and potassium are the most important elements for mineral nutrition in kiwifruit. Lalatta *et al.* (1990) recommended the application of 600 kg/ha N, 250 kg/ha P_2O_5 and 300 kg/ha K_2O for productive vines of kiwifruit.

Although nutritional recommendations are based on responses previously observed in the field trials, yet in the case of kiwifruit, the fertilizer recommendations are tentative. The systematic trials so far conducted are inadequate and the little information available is in no way helpful to devise a judicious nutritional programme. Studies conducted abroad also have limited applicability under our conditions, because of agro-climatic differences. Therefore, the present studies were conducted on the effect of N, P and K fertilizer levels on growth, yield and quality of kiwifruit cv. Allison with the following objectives.

i) To study the effect of NPK fertilizers on growth, yield and fruit quality of kiwifruit cv. Allison.

ii) To study the effect of NPK fertilizers on the leaf nutrient contents.

iii) To work out the best levels of N, P and K fertilizers.

REVIEW OF LITERATURE

Chapter-2

REVIEW OF LITERATURE

Fertilizer application is one of the most important cultural practice, which affects vine growth, yield and fruit quality of kiwifruit. The literature on the effect of fertilizer applications in kiwifruit is scanty and inconclusive. Therefore, an attempt has been made in this chapter to review the relevant literature on N, P and K nutrition on growth, yield, fruit quality and leaf nutrient contents of fruit crops in general and in kiwifruit in particular under different heads.

2.1 EFFECT OF N, P AND K FERTILIZERS ON TREE GROWTH AND VIGOUR

N, P and K fertilizers greatly influence the growth and vigour of fruit plants (Smith and Miller, 1991; Sharma, 1995 and He *et al.*, 2002). Smith and Miller (1991) reported that the application of NPK fertilizer @ 700 or 1420 kg N, 490 or 1090 kg P and 600 or 1200 kg K/ha stimulated the vegetative growth, flower number and root growth in seven-years-old kiwifruit vines. Costa *et al.* (1997) also observed significant increase in shoot length, number of leaves per shoot, leaf area and leaf area index with the application of N fertilizer as compared to the control in kiwifruit. However, Buwalda and Meekings (1993) could not find any significant effect of N application on canopy leaf area in kiwifruit cv, Hayward. Similarly, Tagliavini *et al.* (1995) also reported non-significant effect on stem diameter and pruning wood weight of kiwifruit vines with the combined application of N and P fertilizers.

The application of N @ 150 and 225 kg/ha gave highest shoot growth and dense foliage in grapes (Orphanos, 1992). Crespan *et al.* (1999) reported that application of NPK in the ratio of 12:12:17 (i.e. 1500 kg/ha) produced highest weight of pruning wood in sixteen-year-old grape cv. Cabernet Sauvignon.

Bussi and Defrance (1986) conducted a fertilizer trial on Suncrest cv. of peach with the application of N and K each at 60, 100 and 135 g/tree. They observed that N and K fertilizers exerted significant effects on growth and vigour of tree. Sharma and Singh (1982) reported that application of N @ 120 g/year age of plant produced the better growth as compared to N_{80} and N_{40} g/year of age in Sharbati peach. Similarly, Sharma (1995) obtained increased vegetative growth in peach cv. July Elberta with N and K fertilizers, when applied @ 750:900 g/tree. Application of 700 g N/tree resulted in the highest trunk girth, annual shoot growth and tree volume of peach as compared to other doses of nitrogen (Singh, 1992). Zegbe (1995) also found the best growth in peach with the application of 25 kg/ha each of N, P and K.

Application of nitrogen to soil has been reported to increase growth and vigour of peach tree (Soing *et al.*, 1998, Arora *et al.*, 1999 and Jia *et al.*, 1999). In a fertilizer trial, Singh and Singh (2002) found that 500 g N/tree was the best and most economical treatment for improving the growth and vigour of peach along with 200 g P_2O_5 and 480 g K_2O/ tree. However, Kanwar and Nijjar (1983) could not observe any marked differences on the vigour of Flordasun peach with soil application of N, P and K fertilizers in the ratio of 1500:1000:1000 g/tree.

Swati *et al.* (1990) recorded more tree girth and annual shoot growth with 6 and 5 kg NPK (10:20:20)/ tree in seven-year-old apricot cv. Trevatt. However, Bussi and Amiot (1998) observed that K fertilizers did not affect vegetative growth in apricot cv. Bergaron. In sweet cherry, the increased leaf area and trunk circumference with 90 kg/ha each of N, P_2O_5 and K_2O were observed by Dzhalilova (1991). Similarly, Vitanova (2000) also recorded the maximum annual growth and increment of the tree trunk of plum cv. Stanley with the combined application of 400 kg N, 240 kg P and 300 kg K/ha.

Application of N, P and K fertilizers each @ 60 kg/ha in apple cv. Golden Spur have been reported to increase shoot growth (Treglazova and Fataliev, 1994). Stimulated vegetative growth in apple with N fertilizers was recorded by various workers (Rupp and Hubner, 1995, Hipps *et al.*, 1997 and Tartachinik, 1997). Trunov and Shishkarev (1998) fertilized the apple tree with 130-150 kg N, 30-60 kg P and 120-140 kg K/ha and found that N,P,K fertilizers enhanced the tree growth.

However, Hipps *et al.* (1990) were of the opinion that increasing fertilizer rates from 63 to 189 kg N/ha had either negligible or inconsistent effects on tree growth in apple cv. Cox's Orange Pippin. Similarly, Pacholak (1990) also recorded no increase in tree growth in apple cv. James Grieve with 195 kg N/ha and 120 kg P_2O_5 /ha and 285 kg K_2O/ha.

2.2 EFFECT OF N, P AND K FERTILIZERS ON YIELD

Total yield of quality fruit is an important factor in commercial fruit growing. N and K fertilizers, when applied @ 200 kg N/ha alone and in combination with 200 kg K_2O/ha have been reported to increase fruit yield in kiwifruit cv. Hayward (Testoni *et al.*, 1990). However, they observed a decrease in yield when dose was increased to 300 kg/ha. Clark *et al.* (1992) obtained the doubled yield in kiwifruit cv. Hayward, when vines were fertilized with 1420 kg N/ha. Similarly, Smith and Miller (1991) recorded the higher yield with the application of 1420 kg N/ha, 1090 kg P/ha and 1200 kg K/ha in kiwifruit. Monastra *et al.* (1995) studied the effect of different doses of N, P and K fertilizers and recorded the highest cumulative yield with the application of 150 kg N/ha, 39 kg P_2O_5/ha and 124 kg K_2O/ha in kiwifruit. Similar increase in cumulative yield of kiwifruit with the application of 200 kg N/ha alone and in combination with 50 kg P/ha was observed by Tagliavini *et al.* (1995). Scudellari *et al.* (1996) reported that cumulative yield of kiwifruit increased with increasing N application from 50 to 150 kg/ha, whereas, further increase upto 250 kg N/ha had no beneficial effect on yield.

Increased yield per vine with the application of N fertilization was recorded by Costa *et al.*, (1997) in kiwifruit. In another study, Monastra *et al.* (1997) observed the positive influence on cumulative yield with the application of nitrophoska gold fertilizer as compared to the traditional split application of N, P and K fertilizers. Vizzotto *et al.* (1999) studied the effect of different N levels (0, 150, 300 and 450 kg N/ha) on kiwifruit yield. They found a positive correlation of yield to rate of N fertilization in first year, whereas, opposite trend was observed thereafter. However, Buwalda *et al.* (1990) could not find any significant effect of N application on the yield of kiwifruit.

In kiwifruit, different levels of K had no significant effect on yield (Buwalda and Smith, 1991), however, 200 kg N/ha exhibited significant effect on yield. It has been found that yield in kiwifruit reduced significantly when N supply was limited to 250 or 750 kg N/ha annually (Buwalda and Meekings, 1993). Johnson *et al.* (1997)

also observed non-significant effect on yield with the application of 150, 300 and 450 kg N/ha in kiwifruit.

Bovha (1997) obtained the highest yields of 3087 kg/ha in grapes cv. Laski Risling with the application of NPK fertilizers and lowest in no fertilizer. Maximum yield with the application of 105.4 g N per plant and 308.33 g K_2O per plant in grapes was recorded by Terra *et al.* (2000). Orphanos (1992) found that P and K fertilizer applications had no significant effect on yield, but yield increased linearly with increasing N rates in grape vine cv. Sultanina. However, Males (1998) found little effect on yield in grapes cvs. Emerald Riesling and Rkaciteli with the application of 250 kg N/ha, 200 kg P_2O_5/ha and 400 kg K_2O/ha.

Annual application of N, P_2O_5 and K_2O at 180, 90, 120 kg/ha, respectively were found to be most effective in yield enhancing in 'Jonathan' apple (Chekan, 1988). Lipecki (1990) recorded the highest yield of 28.8 t/ha as compared to control, i.e. 23.0 t/ha, with the application of 150 kg N + 75 kg P_2O_5 and 300 kg K_2O in apple cv. Jonathan. Increased yield in apple with N fertilization was recorded by various workers (Noe *et al.*, 1995, Rupp and Hubner, 1995 and Nosal, 1995).

Piatkowski *et al.* (1990) obtained highest yield in apple with the application of 100 kg N + 50 kg P_2O_5 and 100 kg K_2O/ha. Similarly, Svagzdys (1990) recorded the increased yield by 49.7 per cent with the application of 120 kg N and 180 kg K_2O/ha in addition to phosphogypsum in apple. The application of 90 kg N/ha resulted in the production of highest yield i.e. 102 kg/tree in apple (Velasco *et al.*, 1992). Treglazova and Fataliev (1994) recorded the best result in terms of yield in apple cv. Goldspur with the application of 60 kg/ha each of N, P and K. Highest yield in Antonovka Obyknovennaya' apple was recorded by Voroh (1996) with the application of N, P and K @ 180 kg/ha each. However, Hipps *et al.* (1990) observed that increasing N fertilizer rate from 63 to 189 kg N/ha had either negligible or inconsistent effect on fruit yield in Cox's Orange Pippin apple. Similarly, Pacholak (1990) found reduction in yield with higher NPK rates i.e. 195 kg N, 120 kg P_2O_5 and 285 kg K_2O/ha in apple cv. James Grieve.

Tewari *et al.* (1992) obtained the highest yield in peach with the application of 30 g N and 30 g K/tree. Borghi *et al.* (1995) also recorded the increased fruit yield from 55.9 to 64.6 kg/tree in peaches with the application of 200 kg K_2O/ha. Increased yield in peach cv. Fair haven with 300 kg N/ ha was found by Meheriuk *et al.* (1995). Saenz *et al.* (1997) recorded increased total yield in peach with N applications. Similarly, Arora *et al.* (1999) reported that fruit yield was directly related to N applications in peach trees. However, Marangoni *et al.* (1995) could not find any significant effect on fruit yield in nectarine cv. Stark Redgold with N and K fertilizers.

2.3 EFFECT OF N, P AND K FERTILIZERS ON FRUIT QUALITY

Fruit quality not only includes the organic constituents, but also includes to a great extent, size, shape, flavour, firmness and colour of the fruit. These parameters are significantly affected by fertilizer application to trees.

Application of N, P and K fertilizers have been found to exhibit a considerable influence on fruit size, weight and firmness (Nosal, 1995, Mass *et al.*, 1998 and Wang *et al.*, 2002). Testoni *et al.* (1990) found that K_2O application increased fruit quality, particularly, size, firmness and soluble solid contents, whereas, N application had negative effect on fruit size in kiwifruit cv. Hayward. However, Buwalda *et al.* (1990) found that N application increased fruit size and quality of kiwifruit cv. Hayward. Smith and Miller (1991) reported that NPK (12:10:10) mixture had no adverse effect on changes in softness or soluble solids concentrations of stored fruits. Tagliavini *et al.* (1995) obtained the increased percentage of acceptable size fruits of kiwifruit, when they applied N and P fertilizers in the combination of 100-50 kg/ha respectively. However, Scudellari *et al.* (1996) did not notice any effect on average fruit weight, firmness and TSS at harvest or after cold storage in kiwifruit with the application of 150 kg N/ha.

Fruit quality in terms of flesh firmness and total soluble solids was not significantly affected by increasing N application, but the percentage of marketable fruits was slightly greater with 150 kg N/ha in kiwifruit (Costa *et al.*, 1997). However, Johnson *et al.* (1997) did not observe any significant effect on fruit size with increasing N levels in kiwifruit. Monastra *et al.* (1997) applied 150 kg N/ha, 90 kg P_2O_5/ha and 150 kg K_2O/ha to kiwifruit vines cv. Hayward. They did not observe any significant effect on fruit quality especially on phosphorus, fiber and vitamin C. Vizzotto *et al.* (1999) found that N fertilizers when increased from 0-450 kg/ha resulted in increased total soluble solids contents and decreased ascorbic acid content and early softening of kiwifruit in storage.

Khyat and Dujaili (2001) obtained the increased bunch and berry weight as well as bunch length and diameter in the two growing season in grapes cvs. Kamoli and Halwani with the application of 1.688 kg N/vine. However, Males (1998) found that NPK fertilizers when applied @ 250 kg N/ha, 200 kg P_2O_5/ha and 400 kg K_2O/ha had little effect on average berry weight and total soluble solids content of grapes cvs. Emerald Riesling and Rkaciteli.

Ahad *et al.* (1992) obtained the increased total fruit weight/tree in apple with 2 kg tree each of N, P and K. Noe *et al.* (1995) also observed that TSS contents and fruit firmness were highest in apple cv. Golden Delicious with the application of 50 kg N/ha. Similarly, Lysiak *et al.* (1994) obtained the firmest fruits of apple cv. Cortland, when they applied 80 kg P_2O_5/ha. Vorob (1996) recorded that application of 180 kg/ha each of N, P and K fertilizer significantly improved the fruit size and weight in Antonovka Obyknovennaya apples. However, Pacholak (1990) noticed no marked effect on average fruit weight, TSS and fruit firmness in apple cv. James Grieve with different rates of NPK i.e. 195 kg N/ha, 120 kg P_2O_5 kg/ha and 285 kg K_2O/ha. Nitrogen application had no significant effect on average fruit weight, firmness, total soluble solids and acidity in apple (Muster and Hubner, 1994 and Khattari and Shatat, 1996). Papp *et al.* (1998) observed that 50 kg N/ha had only a slight effect on fruit firmness in apples. However, Komamura *et al.* (2000) recorded the negative effect of excessive N application on fruit firmness, acidity and total soluble solids content and colouring of apple cv. Jonathan.

Singh (1992) reported that application of 500 g N/tree significantly improved fruit size and weight in July Elberta peach. Similarly, Soing *et al.* (1998) obtained the increased fruit size and weight in peach with the increased application of N fertilizers.

Nijjar *et al.* (1972) reported that combined effect of NPK application produced the lowest acidity in comparison to individual application of N, P and K in apricot. Similarly, Sharma *et al.* (1979) reported reduction in titratable acidity with increased application of fertilizers to peach. Choureitah and Lenz (1974) reported that glucose and fructose contents of sour cherry decreased with incresing N levels, whereas, amino acids increased. Verma and Bhandari (1996) reported the highest reducing, non-reducing and total sugar with NPK application. They also observed that titratable acidity increased with increasing level of N.

Tewari *et al.* (1992) also recorded the highest total sugar and ascorbic acid contents with the application of 30 g N + 30 g K/tree in peach. However, Marangoni *et al.* (1995) did not observe any effect on average fruit weight, TSS, acidity and firmness in peach with 100 or 200 kg N/ha and 125 kg K/ha. Similarly, Borghi *et al.* (1995) failed to record any significant effect on average fruit weight in peach with 200 kg K_2O /ha. However, increased percentage of first class fruits, soluble solids contents, ascorbic acids, sugar-acid ratio and flesh firmness in peach cv. Dangshan Suli with the application of potash were recorded by He *et al.* (2002).

2.4 EFFECT OF N, P AND K FERTILIZERS ON LEAF NUTRIENT STATUS

Leaf analysis is a powerful tool to monitor nutrient status of plants. However, the mineral composition of leaves in fruit plants have shown seasonal changes, which may have important consequences in respect to the diagnosis of nutrient disorders and the appropriate time of application.

Testoni *et al.* (1990) observed that in kiwifruit, N and K fertilization had no positive effect on N concentration in the leaves, whereas K content in the leaves decreased with the increase in both N and K fertilization and Fe content increased with N fertilization. Similarly, Lalatta *et al.* (1990) found that leaf K content increased with the decrease of Mg and positive relation was found between P and N leaf contents in kiwifruit with the combined application of 150-300 kg N/ha, 150 P_2O_5 kg/ha and 150-300 kg K_2O/ha. Buwalda *et al.* (1990) noticed the decline in leaf N concentration in kiwifruit cv. Hayward with the increased application of N rates from 0 to 200 kg/ha. On the other hand, Smith and Miller (1991) indicated that N and K concentrations in the leaves of treated vines (4 t and 10 t/ha of NPK mixture i.e. 12:10:10) remained at higher level throughout the growing season compared to those in the control vines of kiwifruit.

Marsh *et al.* (1992) noticed the higher leaf K concentration in kiwifruit with the application of 250 kg KCl/ha. Tagliavini *et al.* (1995) also observed increased N concentration in leaves and petioles of kiwifruit with increased supply of N and higher leaf P concentration with P fertilization as compared to those receiving only N fertilizer. Similarly, Monastra *et al.* (1995) found the higher concentration of N and K in the leaves of kiwifruit cv. Hayward with the application of 150 kg N/ha, 39 kg P_2O_5/ha and 124 kg K_2O/ha as slow release fertilizer. N application at 0, 150, 300 and 450 kg/ha increased the leaf N contents in kiwifruit (Costa *et al.*, 1997). Loupassaki *et al.* (1997) found that K fertilizer application increased leaf K content but depressed P and B in the leaves, while, P fertilizer did not increase the P content in the leaves of kiwifruit cvs. Monty, Bruno, Abbot and Hayward.

Shikhamany *et al.* (1988) applied N @ 300, 600, 900 and 1200 kg/ha and K_2O @ 0, 500, 1000 and 1500 kg/ha annually in grape vine cv. Thompson Seedless and observed that the N application enhanced the Ca, Mg and Mn contents but reduced the concentrations of NO_3-N, total N, P and K in leaf petioles, whereas high K levels increased NO_3-N, K and Cu contents, but reduced Mg and Fe contents.

Kassem *et al.* (1994) recorded the increased leaf N, K and Cu concentrations, but reduced leaf Zn and Mn concentrations in apple cv. Anna with NPK fertilizers. Similarly, Rupp and Hubner (1995) noticed that N fertilizers increased leaf N but decreased leaf P and K concentrations, while leaf Ca and Mg were not affected in apple cv. Golden Delicious. Wrona *et al.* (1995) obtained the higher leaf K concentrations with increasing rate of K fertilizer in apple. Sadowski *et al.* (1995a) also observed increased N contents in the leaves of apple with the application of 120 kg N/ha as compared to control. Jadczuk *et al.* (1998) found the increase in K content and decrease in Mg content in the leaves of apple with the increase in K fertilizers. Similarly, Papp *et al.* (1998) found that increased N application to apple cv. Jonathan, increased leaf N and Mg, but depressed the leaf P and K contents.

In cherry, Georgiev (1988) observed that increasing N rates, increased leaf N and Mn, and reduced P and K contents, but Ca, Mg, Fe, Zn and Cu were not affected markedly. Sadowski *et al.* (1995b) found that application of P fertilizers did not increase leaf P in sour cherry. Highest leaf N content and the lowest leaf P and K contents were recorded in 300 g N/tree whereas, leaf P and K contents were higher with 100 g P_2O_5 /tree and 300 g K_2O/tree in cherry (Ganai *et al.*, 1995). Szucs *et al* (1996) observed that N and P fertilizers had only small effect on leaf nutrient contents, while, K fertilizer was positively correlated to leaf K and negatively to leaf Mg and N in sour cherry. Increase in leaf N concentrations in cherry with the application of 60 kg N/ha was recorded by Sadowski *et al.* (2001).

Sharma and Singh (1982) reported that application of N and K fertilizers to the peach tree resulted in increased concentration of leaf N, Fe, Cu, Mn and Zn contents and decreased concentration of K, Ca, Mg and B. Walsh *et al.* (1989) observed that increasing N fertilization decreased leaf Ca in peaches. Tagliavini *et al.* (1993) was of the opinion that addition of P to the soil increased shoot P concentration and P uptake, but depressed the shoot and leaves N concentrations in peach. Similarly, Meheriuk *et al.* (1995) also observed that with the increase in N levels, there was increase in N content of leaves but P content decreased in peach. Arora *et al.* (1999) reported an increase in leaf N and decrease in leaf P and K contents with increasing N levels in peach. Similarly, Singh and Singh (2002) noticed the positive relationship between the rate of N fertilizer and leaf N, Fe, Mn, Zn and a negative relationship between N rates and leaf P, K and Ca in peach.

2.5 EFFECT OF N, P AND K FERTILIZERS ON NUTRIENT STATUS OF SOIL

There are different views of various workers regarding the effect of soil application of N, P and K fertilizers on soil nutrient status. Further, the information on the effect of these fertilizers on nutrient availability particularly in soil is scanty. An increase in available and total N has been reported by Vitanova (1973) and Kumar (1984) in plum orchards with the application of N fertilizers. Sharma (1995) also reported an increase in available N and K and decrease in available P contents of July Elberta peach orchard with increasing N and K applicarion to the soil. According to Badyal (1980), the increasing level of N application to plum trees increased the available N, P, K, Fe, Mn, Zn, Cu and exchangable Mg and Ca contents of Santa Rosa plum orchards. Sharma (1987) reported an increase in available N, exchangable K, Ca and Mg with increasing levels of N in peach orchard. Whereas, nitrogen fertilizer caused a decrease in K content of the soil (Cummings, 1978 and Kepka *et al.*, 1982).

Singh (1982) reported an increase in available N, P and K in the soil of peach orchard following the application of NPK fertilizers. Similar type of relationship between fertilizer application and available N, P and K contents in soil was reported by Rogers (1969), Havelka (1970), Rom and Arrington (1974) and Stoilov and Marinov (1979) in different fruit trees.

An increase in the concentration of soil N, P, Mg, Fe, Zn and decrease in K, Ca and Cu contents with increasing dose of N to plum orchard have been reported by Khokhar (1984). Bhan (1986) demonstrated that the increase in dose of N increase the available N and Mg and decreased the contents of K and Ca in plum orchard. Sud (1987) reported that increase in N application also increased the available N, K, Mg and Zn contents, while, P, Cu and Mn were better at medium level of N. Singh (1992) revealed that with the increase in level of N, the available N and K contents of the soil increased and P content decreased.

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MATERIALS AND METHODS

Chapter-3

MATERIALS AND METHODS

The present investigations on "Studies on the effect of N, P and K fertilizer levels on growth, yield and quality of kiwifruit cv. Allison" were carried out during 2002-2003.

3.1 EXPERIMENTAL DETAILS

The investigations were conducted on seven-year-old vines of kiwifruit cv. Allison having uniform growth, vigour and size, planted at a spacing of 4 m x 6 m and trained on T-bar system. The vines were given uniform cultural practices during the course of investigations.

The experiment was laid out in randomized block design with three levels of each N (50, 100 and 150 g/year age of vine), P (35, 70 and 105 g/ year age of vine) and K (50, 100 and 150 g/ year age of vine) in twenty seven factorial combinations. Each treatment was replicated three times with one vine under each replication.

Nitrogen was supplied in the form of CAN (25% N), phosphorus through SSP (16% P_2O_5) and potassium through MOP (60% K_2O). Full dose of P and K fertilizers along with FYM (50 kg/vine) was applied in the last week of December, whereas, N was applied in two split doses i.e. half dose of N in first week of March and remaining half dose in the second week of May.

3.2 OBSERVATION RECORDED

3.2.1 Vine growth and vigour

3.2.1.1 Trunk girth

Before the commencement of the experiment, the trunk of each vine under each treatment was marked with red paint at 30 cm above the soil surface. The circumference was measured with the help of measuring tape, before the start of the experiment and after the completion of the experiment and the results were expressed as increase in trunk girth in centimeter (cm).

3.2.1.2 Annual shoot growth

Twenty shoots from the current season's growth were randomly selected from the periphery of each vine. The length of these shoots was measured with a measuring tape at the end of growing period and expressed in centimeter (cm).

3.2.2 Yield

The yield of fruits under different treatments were determined on the basis of total weight of fruits harvested from the vine under each treatment and average yield per vine was calculated. The yield was expressed in kilograms per vine (kg/vine).

3.2.3 Yield of different marketable grades

On the basis of weight, the harvested fruits were classified into three different grades viz., A grade (>70 g), B grade (50-70 g) and C grade (<50 g). The yield of different grades was expressed in kilograms per vine (kg/vine).

3.2.4 Fruit quality

3.2.4.1 Physical characteristics

3.2.4.1.1 Fruit size

The size of fruits was measured in terms of length and diameter. The length and diameter of twenty randomly selected fruits per vine were measured at the time of harvest with the help of a Digimatic vernier calliper (Mitutoyo, Japan). The average fruit length and diameter were calculated and expressed in milimeter (mm).

3.2.4.1.2 Fruit weight

Twenty fruits taken for measuring the fruit size were weighed on a top pan balance. The average weight per fruit under different treatments was calculated and expressed in grams per fruit (g/fruit).

3.2.4.1.3 Flesh firmness

The firmness of fruit at the time of harvest was taken with the help of penetrometer model F+ 327 (3-27 lbs). Thin layer of fruit skin was peeled off with stainless steel knife at three places on the single fruit and the penetrometer was inserted inside the fruit. The pressure was recorded and expressed in kilogram per square centimeter (kg/cm^2).

3.2.4.2 Chemical characteristics

3.2.4.2.1 Total soluble solids

The total soluble solids of the fruit juice was determined with Erma - hand refractrometer (0-32°B) by putting a few drops of juice on the prism. The refractrometer was calibrated with distilled water before use. A temperature correction was applied when it was above or below 20°C (AOAC, 1980). The total soluble solids were expressed as per cent of fresh juice.

3.2.4.2.2 Titratable acidity

Twenty five grams of fruit pulp was thoroughly mixed with distilled water in a warring blender and the volume was made 250 ml. The contents were filtered through Whatman No-1 filter paper. 10 ml of extract was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator. The appearance of pink colour indicated the end point. The total titratable acidity was calculated on the basis of one ml 0.1 N NaOH equivalent to 0.067 g as anhydrous citric acid or per cent citric acid in juice (AOAC, 1980). The remaining filtered solution was used for sugar estimation.

3.2.4.2.3 Total sugars

To the remaining filtrate, 10 ml of saturated lead acetate was added and contents of flask were shaken and filtered. 10 ml of potassium oxalate was later added to precipitate, the excess of lead and the contents were again filtered. 100 ml of filtrate was taken in 250 ml volumetric flask and to this few drops of concentrated HCl was added and the hydrolysis was carried out by leaving it overnight. The excess of acid was then neutralized by adding saturated solution of NaOH. The hydrolyzed solution was taken in a burette and titrated against the boiling mixture of 5 ml each of fehling A and fehling B solutions, using methylene blue as an indicator (AOAC, 1980). The end point was indicated by the appearance of brick red colour and total sugar was worked out as per cent of fresh weight of the fruit pulp.

3.2.4.2.4 Reducing sugars

For estimation of reducing sugars, boiling mixture of 5 ml each of fehling A and felhing B as taken in case of total sugars was titrated with unhydrolyzed solution which was left behind after taking 100 ml for the estimation of total sugars. The same process as given for the estimation of total sugar was followed and the solution used for titration was noted to calculate the per cent reducing sugar.

3.2.4.2.5 Non-reducing sugars

The amount of non-reducing sugars was calculated by substracting the reducing sugars from total sugars and multiplying the difference by a standard factor i.e. 0.95. The results were expressed as per cent non-reducing sugars.

3.2.4.2.6 Ascorbic acid

Ascorbic acid was determined with the help of indophenol solution (2, 6, dichlorophenol indophenol dye). Indophenol dye solution was first standardized against standard ascorbic acid. Then freshly extracted juice was mixed with equal volume of 3 per cent metaphosphoric acid and an aliquot of 10 cc was titrated against standard indophenol solution. The end point was determined by the appearance of rose pink colour which persist for a few seconds (AOAC, 1980).

The indophenol dye and metaphosphoric acid solutions were prepared fresh for each set of experiment and standardized against standard ascorbic acid to calculate the factor. The results were expressed in terms of mg of ascorbic acid in 100 g of fruit pulp.

3.2.5 Determination of leaf nutrient contents

3.2.5.1 Collection and preparation of leaf sample

Leaf samples along with petiole were collected in the first week of August from middle portion of bearing shoots. The sampled leaves were washed first by tap water, followed by 0.1N HCl, distilled water and finally with double distilled water. They were then dried by spreading on clean blotting papers and the final drying was accomplished in oven at 60°C (Chapman, 1964). The samples were subsequently ground by grinder for further analysis.

3.2.5.2 Digestion of leaf samples

The digestion of one gram leaf samples for estimation of nitrogen was carried out in concentrated sulphuric acid by adding digestion mixtures of the following:

Potassium sulphate	-	400 parts
Copper sulphate	-	20 parts
Mercuric oxide	-	3 parts
Selenium powder	-	1 part

For the estimation of other elements, the digestion was done in diacid mixture prepared by mixing nitric acid and perchloric acid in the ratio of 4:1, taking all relevant precautions as suggested by Piper (1966).

3.2.5.3 Determination of nutrient elements

The nitrogen was estimated by micro-kjeldahls method (AOAC, 1980). Phosphorus was determined by vanedo-molybdophosphoric yellow colour method (Jackson, 1967) on spactronic-20. The potassium, calcium, magnesium and micro nutrients viz., iron, zinc, copper and manganese were determined on atomic absorption spectrophotometer.

3.2.6 Soil analysis

3.2.6.1 Collection and preparation of soil samples

Before the start of experiment composite soil sample was collected with the help of screw auger from experimental plot for physico-chemical analyses (Table 1).

The composite soil samples were again drawn at the end of experiment from the basin of each vine. The samples were dried in shade and crushed with the help of wooden pastel and mortar and passed through 2 mm sieve and stored in cloth bags. The soil analysis for various characteristics viz., pH, electrical conductivity, available N, P and K were done as per method given in Table 1.

Table 1. **Chemical characteristics of the experimental orchard soil (0-15 cm depth)**

S. No.	Particulars	Results	Methods
1.	pH	7.25	1:2 soil water suspension glass electrode pH meter (Jackson, 1967)
2.	Electrical conductivity (dsm^{-1})	0.14	1:2 soil water suspension, systronics conductivity meter (Jackson, 1967)
3.	Available nitrogen (kg ha^{-1})	360.07	Alkaline potassium permanganate method (Subbiah and Asijia, 1956)
4.	Available phosphorus (kg ha^{-1})	30.27	Olsen's method of extraction with 0.5 M $NaHCO_3$ at pH 8.5 and development of colour by chlorostannous reduced molybdophorphoric acid (Olsen *et al.* 1954)
5.	Available potassium (kg ha^{-1})	273.33	Ammonium acetate (1N) extraction and determination using flame photometer (Jackson, 1973)

3.2.7 Statistical analysis

The data obtained from the present investigations were statistically analysed by employing Factorial Randomized Block Design in accordance with procedure outlined by Gomez and Gomez (1984). Least square differences at 5 per cent level were worked out to compare the treatment effects and to interpret the differences.

EXPERIMENTAL RESULTS

Chapter-4

EXPERIMENTAL RESULTS

The results obtained during the present investigations on the "Studies on the effect of N, P and K fertilizer levels on growth, yield and quality of kiwifruit cv. Allison" are presented as under:

4.1 EFFECT OF N, P AND K FERTILIZERS ON VINE GROWTH AND VIGOUR

4.1.1 Trunk girth

The data on the effect of NPK fertilizers on trunk girth is presented in Table 2. The data reveals that the trunk girth increased with the increasing dose of N and K. In case of N, the maximum increase in trunk girth (3.59 cm) was recorded in N_{150}, which was significantly higher than N_{100} (3.19 cm) and N_{50} (2.93 cm), The minimum increase in trunk girth (2.93 cm) was observed in N_{50}, which was significantly lower than all other N levels. In case of P, the maximum increase in trunk girth (3.30 cm) was observed in P_{70}, which was statistically at par with P_{105} (3.26 cm). The minimum increase in trunk girth was recorded in P_{35} (3.15 cm), which was also significantly lower than all other levels of P. In K, K_{150} registered the maximum increase in trunk girth (3.32 cm), which was statistically at par with K_{100} (3.30 cm). The minimum increase in trunk girth was recorded in K_{50}, which was significantly lower than K_{150} and K_{100}.

In case of N x P interaction, $N_{150}P_{105}$ and $N_{150}P_{70}$ recorded the maximum increase in trunk girth of 3.61 cm, which was statistically at par with $N_{150}P_{35}$. While the minimum increase in trunk girth was observed in $N_{50}P_{35}$ (2.83 cm), which was statistically at par with $N_{50}P_{70}$ (2.89 cm). In NxK interaction, the maximum increase in trunk girth (3.72 cm) was observed in $N_{150}K_{100}$, which was significantly higher than all other combinations of NxK. The minimum increase in trunk girth (2.78 cm) was recorded in $N_{50}K_{50}$, which was significantly lower than rest of NxK combinations. In case of PxK interaction, the maximum increase in trunk girth (3.56 cm) was recorded in $P_{35}K_{100}$, which was statistically at par with $P_{70}K_{150}$ and $P_{70}K_{50}$. The minimum increase in trunk girth (2.78 cm) was recorded in $P_{35}K_{50}$, which was significantly lower than other combiantions of PxK.

In the combined effect of three factor interactions i.e. NxPxK, the maximum increase in trunk girth (4.00 cm) was recorded in $N_{150}P_{105}K_{100}$, which was found to be significantly higher than all other combinations of NxPxK. The minimum increase in trunk girth (2.33 cm) was observed in $N_{50}P_{35}K_{50}$, which was significantly lower than other combinations of NxPxK.

4.1.2 Annual shoot growth

The data on the effect of NPK fertilizers on annual shoot growth is presented in Table 3. It is evident from the data that different N, P and K levels showed direct relationship with annual shoot growth. In case of N, N_{150} recorded the maximum annual shoot growth (182.3 cm), which was significantly higher than N_{100} (177.3 cm) and N_{50} (173.8 cm). The minimum annual shoot growth (173.8 cm) was recorded in N_{50}, which was found to be statistically less than N_{100} and N_{150}. In P, the maximum annual shoot growth of 181.1 cm was observed in P_{105}, which was significantly higher than P_{70} (176.3 cm) and P_{35} (176.0 cm). However, P_{70} was statistically at par with P_{35}. While in K, the maximum annual shoot growth (179.7 cm) was observed in K [illegible], which was significantly higher than other levels of K. However, the minimum annual shoot growth (176.6 cm) was recorded in K_{50}, which was statistically at par with K [illegible].

In case of two way interaction i.e. NxP, the maximum annual shoot growth (186.4 cm) was observed in $N_{150}P_{105}$, which was significantly higher than all other combinations of NxP. The minimum increase in annual shoot growth (170.2 cm) was recorded in $N_{50}P_{35}$, which was significantly lower than other combinations of NxP. In case of NxK interaction, the maximum annual shoot growth (183.6 cm) was obtained in $N_{150}K_{100}$, which was significantly higher than other NxK combinations. The minimum increase in annual shoot growth (172.5 cm) was observed in $N_{50}K_{50}$, which

Table 2. Main and interaction effect of NPK fertilizers on increase in trunk girth (cm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	2.83	2.89	3.06	2.93	2.78	3.00	3.00
N_{100}	3.06	3.39	3.11	3.19	3.00	3.17	3.39
N_{150}	3.56	3.61	3.61	3.59	3.50	3.72	3.56
Mean	3.15	3.30	3.26		3.09	3.30	3.32

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	2.78	3.56	3.11
P_{70}	3.50	2.89	3.50
P_{105}	3.00	3.44	3.33

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	2.33	3.33	2.83	3.17	2.50	3.00	2.83	3.17	3.17
N_{100}	2.67	3.50	3.00	3.50	2.83	3.83	2.83	3.17	3.33
N_{150}	3.33	3.83	3.50	3.83	3.33	3.67	3.33	4.00	3.50

$CD_{0.05}$

N =	0.04	NxK =	0.07
P =	0.04	PxK =	0.07
K =	0.04	NxPxK =	0.14
NxP =	0.07		

Table 3. Main and interaction effect of NPK fertilizers on annual shoot growth (cm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	172.7	170.2	178.6	173.8	172.5	172.8	176.2
N_{100}	176.4	177.1	178.3	177.3	176.2	176.4	179.2
N_{150}	179.0	181.6	186.4	182.3	181.1	182.2	183.6
Mean	176.0	176.3	181.1		176.6	177.1	179.7

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	176.2	172.6	179.3
P_{70}	171.7	178.5	178.7
P_{105}	181.8	180.3	181.0

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	173.0	169.0	175.5	167.8	167.0	175.9	179.3	179.2	177.2
N_{100}	177.4	172.8	178.9	170.6	183.2	177.5	180.5	173.1	181.2
N_{150}	177.7	175.9	183.5	176.8	185.3	182.6	185.5	188.9	184.7

$CD_{0.05}$

N = 0.71
P = 0.71
K = 0.71
NxP = 1.24
NxK = 1.24
PxK = 1.24
NxPxK = 2.14

was statistically at par with $N_{50}K_{100}$ (172.8 cm). While in PxK interaction, the maximum annual shoot growth (181.8 cm) was recorded in $P_{105}K_{50}$, which was statistically at par with $P_{105}K_{150}$ (181.0 cm) but significantly higher than $P_{70}K_{50}$, which attained minimum annual shoot growth (171.7 cm).

In case of three factor interaction i.e. NxPxK, the maximum annual shoot growth (188.9 cm) was obtained in $N_{150}P_{105}K_{100}$, which was significantly higher than all other combinations of NxPxK. The minimum annual shoot growth (167.0 cm) was recorded in $N_{50}P_{70}K_{100}$, which was statistically at par with $N_{50}P_{70}K_{50}$ (167.8 cm) and $N_{50}P_{35}K_{100}$ (169.0 cm).

4.2 EFFECT OF N, P AND K FERTILIZERS ON YIELD

4.2.1 Total yield

The data on the main effect of NPK fertilizers on yield (Table 4) reveals that increasing doses of N and K showed direct relationship with total yield but P had direct relation upto P_{70} and there after, yield decreased with the increase in dose of phosphorus. The maximum yield of 53.03 kg/vine was obtained in N_{150}, which was statistically at par with N_{100} (52.69 kg/vine), but significantly higher than N_{50} (42.56 kg/vine). In case of P, the maximum yield (51.60 kg/vine) was recorded in P_{70}, which was significantly higher than P_{105} (49.29 kg/vine) and P_{35} (47.39 kg/vine). Among the individual effect of K, K_{150} registered the maximum yield of 54.08 kg/vine, which was significantly higher than K_{100} and K_{50}. However, the minimum yield (43.94 kg/vine) was recorded in K_{50} treatment.

In NxP interaction, $N_{150}P_{70}$ recorded the maximum yield (55.38 kg/vine), which was statistically at par with $N_{100}P_{70}$ (55.08 kg/vine), whereas, the minimum yield (40.01 kg/vine) was obtained in $N_{50}P_{35}$ combination. Similarly in NxK interaction, the maximum yield of 59.44 kg/vine was found in $N_{150}K_{150}$, which was significantly higher than any other NxK combinations. The $N_{50}K_{50}$ combination recorded the minimum yield of 39.53 kg/vine. In PxK interaction, the maximum yield (56.29 kg/vine) was obtained in $P_{70}K_{150}$, which was significantly higher than other combinations of PxK. Whereas, the minimum yield (41.91 kg/vine) was observed in $P_{35}K_{50}$.

The NxPxK interaction also showed significant effect on total yield. The maximum yield (62.12 kg/vine) was recorded in $N_{100}P_{70}K_{150}$, which was significantly higher than all other combinations of NxPxK. However, the minimum yield (36.62 kg/vine) was obtained in $N_{50}P_{35}K_{50}$.

4.2.2 Grade wise yield

4.2.2.1 Grade A

The data pertaining to the effect of NPK fertilizers on yield of A grade fruits is presented in Table 5. The data reveals that among the different levels of N, the highest yield of A grade fruits (21.16 kg/vine) was recorded in N_{150}, which was significantly higher than N_{100} (20.41 kg/vine) and N_{50} (10.83 kg/vine). In case of P, the maximum yield of A grade fruits (18.68 kg/vine) was obtained in P_{70}, which was significantly higher than P_{105} (17.37 kg/vine) and P_{35} (16.35 kg/vine). However, the minimum yield (16.35 kg/vine) was recorded in P_{35}. K fertilizer showed the direct relationship with yield of A grade fruits and it increased with the increase in level of K. The maximum yield of A grade fruits (23.42 kg/vine) was recorded in K_{150}, which was significantly higher than K_{100} (18.87 kg/vine) and K_{50} (10.10 kg/vine). Similarly, K_{100} produced significantly more A grade fruits than K_{50}.

In NxP interaction, $N_{150}P_{70}$ recorded the maximum yield of A grade fruits (23.11 kg/vine), which was statistically at par with $N_{100}P_{70}$ (22.49 kg/vine) and $N_{150}P_{35}$ (22.08 kg/vine). The combination of $N_{50}P_{35}$ produced the minimum yield of A grade fruits (9.15 kg/vine), which was significantly lower than all other combinations of NxP. In case of NxK interaction, the maximum yield of A grade fruits (29.04 kg/vine) was recorded in $N_{150}K_{150}$, which was statistically at par with $N_{100}K_{150}$ (28.11 kg/vine). The minimum yield (8.35 kg/vine) of A grade fruits was observed in $N_{50}K_{50}$, which was significantly lower than other NxK combinations. However, in PxK interaction, the maximum yield of A grade fruits (24.34 kg/vine) was obtained in $P_{70}K_{150}$, which was statistically at par with $P_{105}K_{150}$ (24.09 kg/vine). The minimum yield of A grade fruits (9.05 kg/vine) was obtained in $P_{35}K_{50}$.

Table 4. Main and interaction effect of NPK fertilizers on fruit yield (kg/vine)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	40.01	44.33	43.35	42.56	39.53	43.51	44.64
N_{100}	50.92	55.08	52.08	52.69	45.16	53.47	59.44
N_{150}	51.25	55.38	52.45	53.03	47.12	53.81	58.14
Mean	47.39	51.60	49.29		43.94	50.27	54.08

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	41.91	48.21	52.05
P_{70}	44.88	53.63	56.29
P_{105}	45.02	48.97	53.89

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	36.62	42.50	40.91	40.73	44.73	47.54	41.26	43.32	45.49
N_{100}	43.54	52.65	56.56	44.27	58.85	62.12	47.66	48.92	59.65
N_{150}	45.58	49.47	58.69	49.64	57.30	59.21	46.15	54.67	56.53

$CD_{0.05}$

N = 0.53
P = 0.53
K = 0.53
NxP = 0.92
NxK = 0.92
PxK = 0.92
NxPxK = 1.59

Table 5. Main and interaction effect of NPK fertilizers on yield of 'A' grade fruits (kg/vine)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	9.15	10.43	12.91	10.83	8.35	11.01	13.12
N_{100}	17.81	22.49	20.93	20.41	11.28	21.83	28.11
N_{150}	22.08	23.11	18.28	21.16	10.68	23.75	29.04
Mean	16.35	18.68	17.37		10.10	18.87	23.42

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	9.05	18.15	21.84
P_{70}	10.64	21.04	24.34
P_{105}	10.62	17.41	24.09

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	7.58	10.52	9.34	5.61	11.39	14.28	11.86	11.13	15.74
N_{100}	9.67	15.25	28.50	13.66	25.40	28.42	10.51	24.85	27.42
N_{150}	9.90	28.67	27.67	12.66	26.34	30.33	9.48	16.25	29.12

$CD_{0.05}$

N = 0.61 NxK = 1.04
P = 0.61 PxK = 1.04
K = 0.61 NxPxK = 1.83
NxP = 1.04

In case of three factor interaction i.e. NxPxK, the maximum yield of A grade fruits (30.33 kg/vine) was recorded in $N_{150}P_{70}K_{150}$, which was statistically at par with $N_{150}P_{105}K_{150}$ (29.12 kg/vine), $N_{100}P_{35}K_{150}$ (28.50 kg/vine) and $N_{150}P_{35}K_{100}$ (28.67 kg/vine). However, the minimum yield of A grade fruits (5.61 kg/vine) was recorded in $N_{50}P_{70}K_{50}$, which was significantly lower than all other combinations of NxPxK.

4.2.2.2 Grade B

The data on the influence of NPK fertilizers on yield of B grade fruits (Table 6) reveals that increasing doses of N, P and K showed direct relationship with yield of B grade fruits. The highest level of N (N_{150}) recorded the maximum yield (21.50 kg/vine) of B grade fruits, which was significantly higher than N_{100} (19.26 kg/vine) and N_{50} (15.07 kg/vine). Similarly, N_{100} produced significantly higher yield of B grade fruits than N_{50}. In P, significantly higher yield (19.38 kg/vine) of B grade fruits was recorded in P_{105}. However, lowest yield (17.34 kg/vine) of B grade fruits was recorded in P_{35}. The yield of B grade fruits increased with the increase in dose of K and K_{150} registered the maximum yield of 19.19 kg/vine of B grade fruits, which was significantly higher than K_{100} (18.75 kg/vine) and K_{50} (17.89 kg/vine).

In NxP interaction, $N_{150}P_{70}$ registered the maximum yield (22.09 kg/vine) of B grade fruits, which was significantly higher than all other NxK combinations. Whereas, the minimum yield of B grade fruits (12.87 kg/vine) was observed in $N_{50}P_{35}$, which was also significantly lower than all other combinations of NxP. In NxK interaction, the maximum yield (22.56 kg/vine) of B grade fruits was obtained in $N_{150}K_{50}$, which was significantly higher than all other NxK combinations. The minimum yield (13.95 kg/vine) of B grade fruits was recorded in $N_{50}K_{100}$, which was statistically at par with $N_{50}K_{50}$ (14.25 kg/vine), but lower than other combinations of NxK. In case of PxK interaction, the maximum yield (20.47 kg/vine) was obtained in $P_{70}K_{150}$,which was significantly higher than all other PxK combinations. Whereas, the minimum yield (15.49 kg/vine) of B grade fruits was observed in $P_{35}K_{50}$.

In three factor interaction of NxPxK, the maximum yield (25.22 kg/vine) of B grade fruits was recorded in $N_{150}P_{105}K_{50}$, which was significantly superior than all other combinations of NxPxK. However, the minimum yield of B grade fruits (11.84 kg/vine) was observed in $N_{50}P_{35}K_{150}$, which was also significantly lower than other combinations of NxPxK.

4.2.2.3 Grade C

It is evident from the data presented in Table 7 that various levels of N, P and K exerted significant effect on yield of C grade fruits. Among the individual effect of N, the highest yield of C grade fruits (16.67 kg/vine) was observed in N_{50}, which was statistically superior than N_{100} (12.64 kg/vine) and N_{150} (11.03 kg/vine). The lowest yield (11.03 kg/vine) of C grade fruits was obtained in N_{150}. In case of P, the maximum yield of C grade fruits (13.99 kg/vine) was registered in P_{35}, which was also significantly higher than P_{70} (13.81 kg/vine) and P_{105} (12.55 kg/vine). Similarly, P_{70} treatment produced significantly higher yield of C grade fruits than P_{105}. In K, the maximum yield (16.04 kg/vine) of C grade fruits was obtained in K_{50}, which was significantly higher than K_{100} (12.85 kg/vine) and K_{150} (11.46 kg/vine).

In case of two factor interaction i.e. NxP, the maximum yield (18.00 kg/vine) of C grade fruits was recorded in $N_{50}P_{35}$, which was significantly higher than all other NxP combinations. However, the minimum yield of C grade fruits was observed in $N_{150}P_{105}$ (10.10 kg/vine). In NxK interaction, the maximum yield (18.35 kg/vine) of C grade fruits was recorded in $N_{50}K_{100}$, which was significantly superior to all other NxK combinations. However, the minimum yield was obtained in $N_{100}K_{150}$ (9.66 kg/vine). In case of PxK interaction, the maximum yield (17.65 kg/vine) of C grade fruits was recorded in P[illegible]K[illegible], which was significantly higher than any other combinations of PxK. The minimum yield of C grade fruits was observed in $P_{105}K_{150}$ (10.71 kg/vine).

In three factor interaction of NxPxK, significantly higher yield (19.73 kg/vine) of C grade fruits was observed in $N_{50}P_{35}K_{150}$, closely followed in $N_{100}P_{35}K_{50}$, which was next best treatment produced yield of 19.33 kg/vine of C grade fruits. However, the minimum yield of C grade fruits was observed in $N_{100}P_{35}K_{150}$ (7.33 kg/vine), which was significantly lower than all other combinations of NxPxK.

Table 6. Main and interaction effect of NPK fertilizers on yield of 'B' grade fruits (kg/vine)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	12.87	17.37	14.98	15.07	14.25	13.95	17.02
N_{100}	18.18	17.88	21.72	19.26	16.86	20.18	20.74
N_{150}	20.98	22.09	21.42	21.50	22.56	22.11	19.82
Mean	17.34	19.11	19.38		17.89	18.75	19.19

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	15.49	18.52	18.02
P_{70}	18.35	18.52	20.47
P_{105}	19.83	19.21	19.09

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	13.33	13.43	11.84	16.67	14.58	20.86	12.75	13.84	18.36
N_{100}	14.30	18.67	21.56	14.75	18.23	20.66	21.52	23.64	20.00
N_{150}	18.83	23.45	20.67	23.63	22.74	19.90	25.22	20.15	18.90

$CD_{0.05}$

N	=	0.21	NxK	=	0.36
P	=	0.21	PxK	=	0.36
K	=	0.21	NxPxK	=	0.62
NxP	=	0.36			

Table 7. Main and interaction effect of NPK fertilizers on yield of 'C' grade fruits (kg/vine)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	18.00	16.55	15.47	16.67	17.15	18.35	14.52
N_{100}	11.77	14.09	12.07	12.64	17.62	10.65	9.66
N_{150}	12.19	10.80	10.10	11.03	13.35	9.53	10.21
Mean	13.99	13.81	12.55		16.04	12.85	11.46

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	17.65	12.12	12.19
P_{70}	15.89	14.07	11.48
P_{105}	14.59	12.35	10.71

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	16.33	17.95	19.73	18.45	18.76	12.43	16.68	18.35	11.39
N_{100}	19.33	8.64	7.33	16.86	14.28	11.13	16.66	9.03	10.53
N_{150}	17.28	9.77	9.52	12.35	9.16	10.89	10.42	9.67	10.21

$CD_{0.05}$

N = 0.09
P = 0.09
K = 0.09
NxP = 0.14
NxK = 0.14
PxK = 0.14
NxPxK = 0.26

4.3 EFFECT OF N, P AND K FERTILIZERS ON PHYSICAL CHARACTERISTICS OF FRUITS

4.3.1 Fruit size

4.3.1.1 Fruit length

Perusal of data presented in Table 8. reveals that NPK and their interaction exhibited significant effect on fruit length. The maximum fruit length (67.43 mm) was recorded in N_{150}, which was significantly higher than N_{100} (65.28 mm) and N_{50} (59.99 mm). However, the minimum fruit length (59.99 mm) was found in N_{50}. In case of P, the maximum fruit length was observed in P_{105} (65.24 mm), which was statistically at par with P_{70} (64.64 mm), but significantly higher than P_{35}. However, the minimum fruit length (62.82 mm) was observed in P_{35}. In K, fruit length increased with the increase in dose of K and significantly higher fruit length of 66.24 mm was recorded in K_{150}. However, the minimum fruit length was observed in K_{50} (61.57 mm), which was significantly lower than all other levels of K.

In NxP interaction, the maximum fruit length (68.86 mm) was observed in $N_{150}P_{105}$, which was statistically at par with $N_{150}P_{70}$ (67.83 mm). However, the minimum fruit length was recorded in $N_{50}P_{35}$ (58.97 mm), which was statistically at par with $N_{50}P_{70}$ (59.73 mm). In NxK interaction, the maximum fruit length of 69.45 mm was registered in $N_{150}K_{150}$, which was statistically at par with $N_{100}K_{150}$ (69.13 mm) and $N_{150}K_{100}$ (68.13 mm), but significantly higher than other combinations of NxK. However, the minimum fruit length was observed in $N_{50}K_{50}$ (59.42 mm), which was statistically at par with $N_{100}K_{50}$ (60.58 mm), $N_{50}K_{100}$ (60.42 mm) and $N_{50}K_{150}$ (60.13 mm). While in case of PxK interaction, the maximum fruit length was observed in $P_{70}K_{150}$ (67.24 mm), which was statistically at par with $P_{70}K_{100}$ (65.83 mm), $P_{105}K_{100}$ (65.80 mm) and $P_{105}K_{150}$ (66.05 mm). The minimum fruit length (59.99 mm) was obtained in $P_{35}K_{50}$, which was statistically at par with $P_{70}K_{50}$ (60.85 mm).

In N, P and K interaction, the maximum fruit length was recorded in $N_{100}P_{70}K_{150}$ (71.34 mm), which was statistically at par with $N_{150}P_{70}K_{150}$, $N_{150}P_{70}K_{100}$, $N_{150}P_{105}K_{150}$ and $N_{100}P_{35}K_{150}$. The minimum fruit length (58.08 mm) was found in

$N_{50}P_{35}K_{50}$, which was statistically at par with $N_{100}P_{70}K_{50}$, $N_{100}P_{35}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$, $N_{50}P_{70}K_{50}$, $N_{50}P_{35}K_{150}$ and $N_{50}P_{35}K_{100}$.

4.3.1.2 Fruit breadth

The data pertaining to the effect of NPK fertilizers on fruit breadth is presented in Table 9. The data reveals that fruit breadth increased as the N level increased. The maximum fruit breadth (41.11 mm) was recorded in N_{150}, which was significantly higher than N_{100} (40.13 mm) and N_{50} (38.72 mm). Similarly, N_{100} also produced the fruits of significantly higher breadth as compared to those produced in N_{50} treatment. In P levels, P_{70} registered the maximum fruit breadth (40.27 mm), which was statistically at par with P_{105} (40.04 mm), but significantly higher than P_{35} (39.64 mm). In case of K, the maximum fruit breadth was recorded in K_{150} (40.42 mm), which was statistically at par with K_{100} (40.16 mm) but significantly higher than K_{50} (39.38 mm), which had minimum fruit breadth.

In case of NxP interaction, the maximum fruit breadth was recorded in $N_{150}P_{70}$ (41.86 mm), which was significantly higher than all other combinations of NxP. The minimum fruit breadth was observed in $N_{50}P_{105}$ (38.61 mm), which was statistically at par with $N_{100}P_{35}$, $N_{50}P_{70}$ and $N_{50}P_{35}$. In case of NxK interaction, the maximum fruit breadth (41.88 mm) was obtained in $N_{150}K_{150}$, which was statistically at par with $N_{100}K_{150}$ (41.15 mm). Whereas, the minimum fruit breadth was recorded in $N_{50}K_{150}$ (38.22 mm). This treatment was statistically at par with $N_{100}K_{50}$ and $N_{50}K_{50}$ combinations. In PxK interaction, the maximum fruit breadth (40.86 mm) was recorded in $P_{35}K_{100}$, which was statistically at par with $P_{105}K_{150}$, $P_{70}K_{150}$ and $P_{35}K_{150}$. The minimum fruit breadth (39.04 mm) was observed in $P_{35}K_{50}$, which was statistically at par with $P_{105}K_{50}$, $P_{105}K_{100}$, $P_{70}K_{50}$ and $P_{35}K_{100}$.

In NxPxK interaction, the maximum fruit breadth (42.32 mm) was recorded in $N_{100}P_{70}K_{150}$, which was statistically at par with $N_{150}P_{105}K_{50}$, $N_{150}P_{70}K_{150}$, $N_{150}P_{70}K_{100}$, $N_{150}P_{70}K_{50}$, $N_{150}P_{35}K_{150}$, $N_{100}P_{105}K_{150}$ and $N_{100}P_{70}K_{100}$. However, the minimum fruit breadth (37.27 mm) was observed in $N_{100}P_{35}K_{50}$, which was statistically at par with $N_{50}P_{35}K_{150}$, $N_{50}P_{105}K_{100}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{35}K_{150}$ and $N_{50}P_{35}K_{50}$.

Table 8. Main and interaction effect of NPK fertilizers on fruit length (mm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	58.97	59.73	61.28	59.99	59.42	60.42	60.13
N_{100}	63.89	66.37	65.60	65.28	60.58	66.14	69.13
N_{150}	65.61	67.83	68.86	67.43	64.72	68.13	69.45
Mean	62.82	64.64	65.24		61.57	64.90	66.24

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	59.99	63.06	65.42
P_{70}	60.85	65.83	67.24
P_{105}	63.89	65.80	66.05

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	58.08	60.17	58.65	58.46	60.18	60.54	61.73	60.90	61.21
N_{100}	59.82	62.82	69.03	60.06	67.69	71.34	61.86	67.92	67.01
N_{150}	62.07	66.18	68.59	64.03	69.62	69.84	68.07	68.58	69.92

$CD_{0.05}$

N	= 0.85	NxK	= 1.48
P	= 0.85	PxK	= 1.48
K	= 0.85	NxPxK	= 2.57
NxP	= 1.48		

Table 9. Main and interaction effect of NPK fertilizers on fruit breadth (mm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	38.72	38.83	38.61	38.72	38.51	39.43	38.22
N_{100}	39.44	40.13	40.81	40.13	38.97	40.26	41.15
N_{150}	40.77	41.86	40.71	41.11	40.66	40.80	41.88
Mean	39.64	40.27	40.04		39.38	40.16	40.42

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	39.04	39.83	40.06
P_{70}	39.35	40.86	40.62
P_{105}	39.76	39.80	40.57

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	37.82	39.83	38.50	38.92	39.83	37.73	38.79	38.82	38.23
N_{100}	39.40	39.31	39.61	37.27	40.82	42.32	40.26	40.26	41.91
N_{150}	39.89	40.36	42.05	41.86	41.92	41.81	40.22	40.33	41.57

$CD_{0.05}$

N	=	0.54	NxK	=	0.94
P	=	0.54	PxK	=	0.94
K	=	0.54	NxPxK	=	1.63
NxP	=	0.94			

4.3.2 Fruit weight

The data pertaining to the effect of NPK fertilizers with respect to fruit weight is presented in Table 10. The perusal of data indicate that the average fruit weight was significantly influenced by different levels of N, P and K. The maximum fruit weight (66.64 g) was recorded in N_{150}, which was significantly higher than N_{100} (64.40 g) and N_{50} (57.36 g). In case of P, significantly higher fruit weight (63.80 g) was recorded in P_{105}. However, the minimum fruit weight (61.39 g) was found in P_{35}, which was significantly lower than P_{105} and P_{70}. In K, the maximum fruit weight (66.45 g) was recorded in K_{150}, which was significantly higher than K_{100} (62.78 g) and K_{50} (59.17 g).

Under NxP interaction, the maximum fruit weight (67.87 g) was recorded in $N_{150}P_{70}$, which was significantly higher than all other combinations of NxP. While, the minimum fruit weight was observed in $N_{50}P_{35}$ (56.91 g). This treatment was statistically at par with $N_{50}P_{105}$ (57.68 g) and $N_{50}P_{70}$ (57.47 g) in respect to fruit weight. In NxK interaction, the maximum fruit weight (70.86 g) was recorded in $N_{100}K_{150}$, which was found to be statistically at par with $N_{150}K_{150}$ (70.67 g). However, the minimum fruit weight (56.26 g) was registered in $N_{50}K_{50}$, which was significantly lower than any other combinations of NxK.

Similarly, in PxK interaction, $P_{70}K_{150}$ registered the maximum fruit weight of 68.08 g, which was significantly different from all other combinations of PxK. However, the minimum fruit weight was recorded in $P_{35}K_{50}$ (58.49 g), which was statistically at par with $P_{70}K_{50}$ (58.88 g).

Three factor interaction of NxPxK was also found significant, and the maximum fruit weight of 73.51 g was recorded in $N_{100}P_{70}K_{150}$, which was statistically at par with $N_{150}P_{70}K_{150}$ (72.12 g), but significantly higher than other combinations of N, P and K. However, the minimum fruit weight was recorded in $N_{50}P_{70}K_{50}$ (55.15 g), which was statistically at par with $N_{50}P_{35}K_{50}$ (56.17 g).

4.3.3 Flesh firmness

The data on the effect of NPK fertilizers on flesh firmness is presented in Table 11. A perusal of data indicate that different levels of N and P showed the non-significant effect on flesh firmness. In case of K, K_{150} recorded the maximum flesh firmness (7.05 kg/cm^2), which was significantly higher than K_{100} (6.82 kg/cm^2) and K_{50} (6.78 kg/cm^2). K_{100} was statistically at par with K_{50} in respect to flesh firmness.

In NxP interaction, the maximum flesh firmness of 7.42 kg/cm^2 was recorded in $N_{100}P_{70}$, which was significantly superior than rest of the NxP combinations. The minimum flesh firmness was found in $N_{50}P_{70}$ (6.70 kg/cm^2), which was at par with all other NxP combinations except $N_{100}P_{70}$. In case of NxK interaction, $N_{100}K_{150}$ registered the maximum flesh firmness of 7.14 kg/cm^2, which was statistically at par with $N_{150}K_{150}$, $N_{50}K_{150}$, $N_{150}K_{100}$, $N_{100}K_{50}$ and $N_{100}K_{100}$. However, the minimum fruit firmness (6.72 kg/cm^2) was recorded in $N_{50}K_{50}$ and $N_{50}K_{100}$, which was statistically at par with all the NxK combinations except $N_{100}K_{150}$. In PxK interaction, the maximum flesh firmness (7.23 kg/cm^2) was recorded in $P_{70}K_{100}$. This treatment was statistically at par with $P_{150}K_{150}$, $P_{70}K_{50}$ and $P_{35}K_{150}$ in respect of flesh firmness. Whereas, the minimum flesh firmness was observed in $P_{105}K_{50}$ (6.60 kg/cm^2), which was statistically at par with $P_{105}K_{100}$, $P_{70}K_{150}$, $P_{35}K_{50}$ and $P_{35}K_{100}$.

In three factor interaction i.e. NxPxK, the maximum flesh firmness (7.63 kg/cm^2) was recorded in $N_{100}P_{70}K_{50}$, which was statistically at par with $N_{150}P_{70}K_{100}$, $N_{150}P_{35}K_{150}$, $N_{100}P_{105}K_{150}$, $N_{100}P_{70}K_{100}$, $N_{100}P_{35}K_{150}$ and $N_{50}P_{105}K_{150}$ While, the minimum flesh firmness (6:40 kg/cm^2) was observed in $N_{150}P_{70}K_{50}$, which was statistically at par with $N_{150}P_{105}K_{150}$, $N_{150}P_{105}K_{100}$, $N_{150}P_{105}K_{50}$, $N_{150}P_{70}K_{150}$, $N_{150}P_{35}K_{100}$, $N_{150}P_{35}K_{50}$, $N_{150}P_{105}K_{100}$, $N_{100}P_{105}K_{50}$, $N_{100}P_{35}K_{100}$, $N_{50}P_{105}K_{100}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$, $N_{50}P_{70}K_{50}$, $N_{50}P_{35}K_{150}$, $N_{50}P_{35}K_{100}$ and $N_{50}P_{35}K_{50}$.

4.4 EFFECT OF N, P AND K FERTILIZERS ON CHEMICAL CHARACTERISTICS OF FRUITS

4.4.1 Total soluble solids (TSS)

The data on the effect of N, P and K fertilizers on TSS of kiwifruit is presented in Table 12. The effect of various levels of N and P on TSS was found to be non-significant, however, different levels of K exerted significant influence on TSS contents of kiwifruit. In case of K, maximum TSS was observed in K_{150} (11.78%),

Table 10. Main and interaction effect of NPK fertilizers on fruit weight (g)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	56.91	57.47	57.68	57.36	56.26	57.99	57.82
N_{100}	62.17	66.06	64.98	64.40	59.05	63.29	70.86
N_{150}	65.08	67.87	66.98	66.64	62.19	67.08	70.67
Mean	61.39	63.21	63.80		59.17	62.78	66.45

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	58.49	60.81	64.86
P_{70}	58.88	64.44	68.08
P_{105}	60.13	63.10	66.40

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	56.17	57.65	56.92	55.15	58.66	58.61	57.47	57.65	57.92
N_{100}	58.53	60.25	67.73	58.78	65.88	73.51	59.85	63.73	71.35
N_{150}	60.77	64.54	69.93	62.73	68.77	72.12	63.06	67.93	69.94

$CD_{0.05}$

N = 0.50
P = 0.50
K = 0.50
NxP = 0.88
NxK = 0.88
PxK = 0.88
NxPxK = 1.52

Table 11. Main and interaction effect of NPK fertilizers on flesh firmness (kg/cm^2)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	6.87	6.70	6.90	6.82	6.72	6.72	7.02
N_{100}	6.84	7.42	6.78	7.02	7.02	6.88	7.14
N_{150}	6.81	6.90	6.73	6.82	6.59	6.87	6.99
Mean	6.84	7.01	6.81		6.78	6.82	7.05

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	6.78	6.61	7.13
P_{70}	6.96	7.23	6.83
P_{105}	6.60	6.62	7.19

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	6.90	6.80	6.90	6.83	6.53	6.73	6.43	6.83	7.43
N_{100}	6.83	6.53	7.17	7.63	7.60	7.03	6.60	6.50	7.23
N_{150}	6.60	6.50	7.33	6.40	7.57	6.57	6.77	6.53	6.90

$CD_{0.05}$

N	=	NS	NxK	=	0.32
P	=	NS	PxK	=	0.32
K	=	0.20	NxPxK	=	0.51
NxP	=	0.32			

Table 12. Main and interaction effect of NPK fertilizers on total soluble solids (%)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	11.44	11.00	12.22	11.56	11.33	11.33	12.00
N_{100}	11.11	11.89	10.67	11.22	11.33	10.89	11.44
N_{150}	10.67	11.22	11.67	11.19	10.56	11.11	11.89
Mean	11.07	11.37	11.52		11.07	11.11	11.78

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	10.89	10.33	12.00
P_{70}	10.89	11.44	11.78
P_{105}	11.44	11.56	11.56

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	12.00	10.67	11.67	10.00	11.00	12.00	12.00	12.33	12.33
N_{100}	11.00	10.00	12.33	12.33	12.33	11.00	10.67	10.33	11.00
N_{150}	9.67	10.33	12.00	10.33	11.60	12.33	11.67	12.00	11.33

$CD_{0.05}$

N	=	NS	NxK	=	0.86
P	=	NS	PxK	=	0.86
K	=	0.49	NxPxK	=	1.49
NxP	=	0.86			

while the minimum was recorded in K_{50} (11.07%), which was statistically at par with K_{100} (11.11%).

The interaction effects of NxP, NxK and Pxk were found significant in respect to TSS contents of the fruit. In the interaction of NxP, the maximum TSS was registered in $N_{50}P_{105}$ (12.22%), which was statistically at par with $N_{50}P_{35}$, $N_{100}P_{70}$ and $N_{150}P_{105}$. However, the minimum TSS was recorded in $N_{100}P_{105}$ and $N_{150}P_{35}$ (10.67%), which was statistically at par with $N_{50}P_{35}$, $N_{50}P_{70}$, $N_{100}P_{35}$ and $N_{150}P_{70}$. Whereas, in NxK interaction, the maximum TSS (12.00%) was recorded in $N_{50}K_{150}$, which was statistically at par with $N_{50}K_{50}$, $N_{50}K_{100}$, $N_{100}K_{50}$, $N_{100}K_{150}$ and $N_{150}K_{150}$. The minimum TSS was found in $N_{150}K_{50}$ (10.56%), which was statistically at par with $N_{50}K_{50}$, $N_{50}K_{100}$, $N_{100}K_{50}$, $N_{100}K_{100}$ and $N_{150}K_{100}$.

In PxK interaction, the maximum TSS was observed in $P_{35}K_{150}$ (12.00%), which was at par with $P_{70}K_{100}$, $P_{70}K_{150}$, $P_{105}K_{50}$, $P_{105}K_{100}$ and $P_{105}K_{150}$. While the minimum TSS (10.33%) was recorded in $P_{35}K_{100}$, which was statistically at par with $P_{35}K_{50}$ and $P_{70}K_{50}$.

In case of three factor interaction of NxPxK, the maximum TSS (12.33%) was recorded in $N_{150}P_{70}K_{150}$, $N_{100}P_{70}K_{100}$, $N_{100}P_{70}K_{50}$, $N_{100}P_{35}K_{150}$, $N_{50}P_{105}K_{100}$ and $N_{50}P_{105}K_{150}$, which was statistically at par with $N_{150}P_{105}K_{150}$, $N_{150}P_{105}K_{100}$, $N_{150}P_{105}K_{50}$, $N_{150}P_{70}K_{100}$, $N_{150}P_{35}K_{150}$, $N_{100}P_{105}K_{150}$, $N_{100}P_{70}K_{150}$, $N_{100}P_{35}K_{50}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$, $N_{50}P_{35}K_{150}$ and $N_{50}P_{35}K_{50}$, but significantly higher than other combinations of NxPxK. The minimum TSS (9.67%) was recorded in $N_{150}P_{35}K_{50}$, which was statistically at par with $N_{150}P_{70}K_{50}$, $N_{150}P_{35}K_{100}$, $N_{100}P_{105}K_{150}$, $N_{100}P_{105}K_{100}$, $N_{100}P_{105}K_{50}$, $N_{100}P_{70}K_{150}$, $N_{100}P_{35}K_{100}$, $K_{100}P_{35}K_{50}$, $N_{50}P_{70}K_{100}$, $N_{50}P_{70}K_{50}$ and $N_{50}P_{35}K_{100}$.

4.2.2 Acidity

The data on the effect of NPK fertilizers on titratable acidity is presented in Table 13. It is evident from the table that different levels of N showed direct relationship, while, P and K showed the inverse relation with titratable acidity. In case of N, the maximum titratable acidity was recorded in N_{150} (0.88%), which was significantly higher than N_{100} and N_{50}. However, the minimum acidity (0.81%) was observed in N_{50}, which was statistically at par with N_{100}. In case of P, the maximum acidity was recorded in P_{35} (0.95%), which was significantly superior than P_{105} (0.73%) and P_{70} (0.84%). In case of K, the maximum titratable acidity (0.91%) was observed in K_{50}, which was significantly higher than all other levels of K. However, the minimum acidity was registered in K_{150} (0.78%), which was statistically at par with K_{100} (0.83%).

In NxP interaction, the maximum acidity (0.97%) was recorded $N_{150}P_{35}$, which was statistically at par with $N_{150}P_{70}$, $N_{100}P_{35}$ and $N_{50}P_{35}$. Whereas, the minimum acidity was observed in $N_{50}P_{105}$ (0.68%), which was statistically at par with $N_{150}P_{105}$ and $N_{100}P_{105}$. In case of NxK interaction, the maximum acidity was recorded in $N_{150}K_{50}$ (0.95%), which was statistically at par with $N_{150}K_{100}$, $N_{100}K_{50}$ and $N_{50}K_{50}$. However, the minimum acidity was observed in $N_{50}K_{150}$ (0.72%), which was statistically at par with $N_{150}K_{150}$, $N_{100}K_{150}$, $N_{100}K_{100}$ and $N_{50}K_{100}$. In case of PxK interaction, the maximum acidity was registered in $P_{70}K_{50}$ (1.03%), which was statistically at par with $P_{35}K_{150}$, $P_{35}K_{100}$ and $P_{35}K_{50}$. While, the minimum acidity was registered with $P_{105}K_{150}$ (0.68%), which was at par with $P_{105}K_{100}$, $P_{105}K_{50}$, $P_{70}K_{150}$ and $P_{70}K_{100}$.

In three factor interaction i.e. NxPxK, the maximum titratable acidity (1.08%) was recorded in $N_{50}P_{35}K_{50}$ which was statistically at par with $N_{150}P_{70}K_{50}$, $N_{150}P_{35}K_{150}$, $N_{150}P_{35}K_{100}$, $N_{150}P_{35}K_{50}$, $N_{100}P_{70}K_{50}$, $N_{100}P_{35}K_{150}$, $N_{50}P_{70}K_{50}$ and $N_{50}P_{35}K_{100}$. The minimum titratable acidity (0.66%) was recorded in $N_{100}P_{105}K_{150}$, $N_{100}P_{105}K_{50}$ and $N_{50}P_{105}K_{150}$, which was statistically at par with $N_{150}P_{105}K_{150}$, $N_{150}P_{105}K_{100}$, $N_{150}P_{70}K_{150}$, $N_{150}P_{70}K_{100}$, $N_{100}P_{105}K_{100}$, $N_{100}P_{70}K_{150}$, $N_{100}P_{70}K_{100}$, $N_{50}P_{105}K_{100}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$ and $N_{50}P_{35}K_{150}$ and significantly lower than other combinations of NxPxK.

4.2.3 Total sugars

The data on the effect of N, P and K fertilizers on total sugars of kiwifruit cv. Allison is presented in Table 14. The data reveals that different levels of N, P and K produced significant effect on total sugars. N showed the inverse relation, while P and K had direct relationship on total sugars. In case of N, the highest total sugars was

Table 13. Main and interaction effect of NPK fertilizers on per cent titratable acidity

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	0.94	0.82	0.68	0.81	0.92	0.80	0.72
N_{100}	0.92	0.85	0.72	0.83	0.85	0.83	0.80
N_{150}	0.97	0.86	0.79	0.88	0.95	0.86	0.83
Mean	0.95	0.84	0.73		0.91	0.83	0.78

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	0.95	0.95	0.94
P_{70}	1.03	0.78	0.73
P_{105}	0.75	0.75	0.68

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	1.08	0.97	0.78	0.99	0.76	0.71	0.70	0.67	0.66
N_{100}	0.85	0.87	1.03	1.04	0.78	0.72	0.66	0.84	0.66
N_{150}	0.91	1.00	1.01	1.05	0.80	0.74	0.88	0.76	0.73

$CD_{0.05}$

N	=	0.06	NxK	=	0.11
P	=	0.06	PxK	=	0.11
K	=	0.06	NxPxK	=	0.18
NxP	=	0.11			

Table 14. Main and interaction effect of NPK fertilizers on per cent total sugars

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	7.84	7.74	7.78	7.78	7.16	7.72	8.47
N_{100}	7.34	7.77	7.77	7.63	7.20	7.82	7.86
N_{150}	7.34	7.52	7.72	7.53	7.06	7.55	7.97
Mean	7.50	7.68	7.76		7.14	7.70	8.10

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	7.78	6.67	8.06
P_{70}	7.16	8.23	7.64
P_{105}	6.47	8.20	8.60

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	7.53	6.62	9.35	7.27	8.02	7.92	6.67	8.51	8.15
N_{100}	8.10	6.87	7.03	7.17	8.39	7.75	6.32	8.20	8.79
N_{150}	7.71	6.51	7.79	7.05	8.26	7.25	6.40	7.88	8.87

$CD_{0.05}$

N = 0.07
P = 0.07
K = 0.07
NxP = 0.12
NxK = 0.12
PxK = 0.12
NxPxK = 0.20

observed in N_{50} (7.78%), which was significantly higher than N_{100} (7.63%) and N_{150} (7.53%). In case of P, highest total sugars (7.76%) was observed in P_{105}, which was significantly better than P_{70} (7.68%) and P_{35} (7.50%). Similarly in case of K, K_{150} recorded the maximum total sugar contents (8.10%), which was significantly higher than K_{100} (7.70%) and K_{50} (7.14%).

In NxP interaction, $N_{50}P_{35}$ registered the maximum total sugars contents (7.84%), which was statistically at par with $N_{150}P_{105}$, $N_{100}P_{105}$, $N_{100}P_{70}$, $N_{50}P_{105}$ and $N_{50}P_{70}$. However, the minimum total sugars (7.34%) was recorded in $N_{150}P_{35}$ and $N_{100}P_{35}$, which was significantly lower than all other combinations of NxP. In case of NxK interaction, the maximum total sugars (8.47%) were recorded in $N_{50}K_{150}$, which was significantly higher than rest of NxK combinations. The minimum total sugars (7.06%) was recorded in $N_{150}K_{50}$, which was statistically at par with $N_{50}K_{50}$ (7.16%). In PxK interaction, the maximum total sugars (8.60%) was observed in $P_{105}K_{150}$, which was significantly higher than other PxK combinations. The minimum total sugars (6.47%) was found in $P_{105}K_{50}$, which was significantly lowest than rest of PxK combinations.

In NxPxK interaction, $N_{50}P_{35}K_{150}$ recorded the maximum total sugars (9.35%), which was significantly higher than all other NxPxK combinations. However, the minimum total sugars (6.32%) was recorded in $N_{100}P_{105}K_{50}$, which was statistically at par with $N_{150}P_{105}K_{50}$ and $N_{150}P_{35}K_{100}$.

4.2.4 Reducing sugars

The data pertaining to the effect of N, P and K fertilizers on reducing sugars is presented in Table 15. The N showed an inverse relation with reducing sugars. Whereas, different levels of P and K showed the direct relationship with reducing sugars. In case of N, the maximum reducing sugars (5.67%) was recorded in N_{50}, which was statistically at par with N_{100} (5.56%), but significantly higher than N_{150} (5.40%). In case of P, the maximum reducing sugars (5.84%) was observed in P_{105}, which was significantly higher than P_{70} (5.59%) and P_{35} (5.19%). In case of K, K_{150} registered the maximum reducing sugars (5.74%), which was statistically at par with

K_{100} (5.63%). The minimum reducing sugars was recorded in K_{50} (5.26%), which was significantly lower than other levels of K.

In case of NxP interaction, the maximum reducing sugars (5.90%) was registered in $N_{100}P_{70}$, which was statistically at par with $N_{150}P_{105}$, $N_{100}P_{105}$ and $N_{50}P_{105}$. However, the minimum reducing sugars (4.92%) was observed in $N_{100}P_{35}$. Similarly in NxK interaction, $N_{100}K_{150}$ registered the maximum reducing sugars (5.88%), which was statistically at par with $N_{150}K_{100}$, $N_{50}K_{150}$ and $N_{50}K_{100}$. The minimum reducing sugars (4.84%) was recorded in $N_{150}K_{50}$, which was significantly lower than all other combinations of NxK. In case of PxK interaction, the maximum reducing sugars (5.94%) was recorded in $P_{105}K_{100}$, which was statistically at par with $P_{70}K_{100}$ and $P_{105}K_{150}$. The minimum reducing sugars (4.88%) was observed in $P_{35}K_{50}$, which was statistically at par with $P_{35}K_{100}$.

In case of NxPxK interaction, the maximum reducing sugars (5.99%) was found in $N_{100}P_{70}K_{100}$, which was statistically at par with $N_{150}P_{105}K_{150}$, $N_{150}P_{105}K_{100}$, $N_{150}P_{105}K_{50}$, $N_{150}P_{70}K_{100}$, $N_{100}P_{105}K_{150}$, $N_{100}P_{105}K_{100}$, $N_{100}P_{105}K_{50}$, $N_{100}P_{70}K_{150}$, $N_{100}P_{70}K_{50}$, $N_{100}P_{35}K_{150}$, $N_{50}P_{105}K_{150}$, $N_{50}P_{105}K_{100}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$ and $N_{50}P_{35}K_{50}$. The minimum reducing sugars (4.25%) was recorded in $N_{150}P_{35}K_{50}$, which was statistically at par with $N_{150}P_{70}K_{50}$, $N_{100}P_{35}K_{100}$ and $N_{100}P_{35}K_{50}$.

4.2.5 Non-reducing sugars

The data on the effect of N, P and K fertilizers on non-reducing sugars is presented in Table 16. In case of N, the maximum non-reducing sugars (2.49%) was recorded in N_{50}, which was significantly higher than N_{100} (2.06%) and N_{150} (1.99%). In P, the maximum non-reducing sugars (2.61%) was observed in P_{105}, which was also significantly higher than P_{70} (2.28%) and P_{35} (1.65%). Similarly, P_{70} was significantly higher than P_{35}. In case of K, K_{150} registered the maximum non-reducing sugars (2.52%), which was significantly higher than all other levels of K. The minimum non-reducing sugars (1.99%) was recorded in K_{50}, which was statistically at par with K_{100} (2.02%).

Table 15. Main and interaction effect of NPK fertilizers on per cent reducing sugars

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	5.58	5.62	5.80	5.67	5.59	5.72	5.69
N_{100}	4.92	5.90	5.85	5.56	5.35	5.45	5.88
N_{150}	5.06	5.26	5.88	5.40	4.84	5.72	5.64
Mean	5.19	5.59	5.84		5.26	5.63	5.74

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	4.88	5.06	5.63
P_{70}	5.18	5.89	5.71
P_{105}	5.71	5.94	5.88

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	5.78	5.47	5.49	5.25	5.78	5.83	5.73	5.91	5.76
N_{100}	4.59	4.41	5.76	5.81	5.99	5.90	5.65	5.93	5.98
N_{150}	4.25	5.31	5.62	4.49	5.89	5.40	5.77	5.96	5.91

$CD_{0.05}$

N = 0.12
P = 0.12
K = 0.12
NxP = 0.21
NxK = 0.21
PxK = 0.21
NxPxK = 0.36

Table 16. Main and interaction effect of NPK fertilizers on per cent non-reducing sugars

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	1.95	2.84	2.68	2.49	2.07	2.65	2.74
N_{100}	1.51	2.14	2.53	2.06	1.97	1.80	2.41
N_{150}	1.49	1.86	2.63	1.99	1.94	1.63	2.40
Mean	1.65	2.28	2.61		1.99	2.02	2.52

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	0.79	2.07	2.10
P_{70}	2.60	1.61	2.62
P_{105}	2.60	2.40	2.83

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	0.71	1.76	3.39	3.11	3.18	2.22	2.40	3.02	2.61
N_{100}	0.75	1.98	1.81	2.38	1.15	2.89	2.77	2.27	2.55
N_{150}	0.89	2.47	1.10	2.30	0.51	2.77	2.63	1.91	3.34

$CD_{0.05}$

N = 0.20
P = 0.20
K = 0.20
NxP = 0.34
NxK = 0.34
PxK = 0.34
NxPxK = 0.59

In NxP interaction, $N_{50}P_{70}$ registered the maximum non-reducing sugars (2.84%), which was statistically at par with $N_{150}P_{105}$, $N_{100}P_{105}$ and $N_{50}P_{105}$. The minimum non-reducing sugars (1.49%) was found in $N_{150}P_{35}$, which was statistically at par with $N_{100}P_{35}$ (1.51%). Similarly in NxK interaction, the maximum non-reducing sugars (2.74%) was recorded in $N_{50}K_{150}$, which was statistically at par with $N_{150}K_{150}$, $N_{100}K_{150}$ and $N_{50}K_{100}$. The minimum non-reducing sugars (1.63%) was observed in $N_{150}K_{100}$, which was statistically at par with $N_{150}K_{50}$, $N_{100}K_{100}$ and $N_{100}K_{50}$. In case of PxK interaction, $P_{105}K_{150}$ registered the maximum amount of non-reducing sugars (2.83), which was statistically at par with $P_{105}K_{50}$, $P_{70}K_{150}$ and $P_{70}K_{50}$. The minimum non-reducing sugars (0.79%) was observed in $P_{35}K_{50}$, which was significantly lower than all other combinations of PxK.

In three factor interactions of NxPxK, the maximum non-reducing sugars (3.39%) was recorded in $N_{50}P_{35}K_{150}$, which was statistically at par with $N_{150}P_{105}K_{150}$, $N_{100}P_{70}K_{150}$, $N_{50}P_{105}K_{100}$, $N_{50}P_{70}K_{50}$ and $N_{50}P_{70}K_{100}$. However, the minimum non-reducing sugars (0.51%) was recorded in $N_{150}P_{70}K_{100}$, which was statistically at par with $N_{150}P_{35}K_{150}$, $N_{150}P_{35}K_{50}$, $N_{100}P_{35}K_{50}$ and $N_{50}P_{35}K_{50}$.

4.2.6 Ascorbic acid

The data on the effect of NPK fertilizers on ascorbic acid content is presented in Table 17. The data indicate that ascorbic acid content decreased with increase in N and P levels. In case of N, the maximum ascorbic acid content was recorded in N_{50} (65.95 mg/100 g), which was significantly higher than other levels of N. While, the minimum ascorbic acid content was observed in N_{150} (64.23 mg/100 g), which was statistically at par with N_{100} (64.28 mg/100 g). In case of P, the maximum ascorbic acid content (65.52 mg/100 g) was recorded in P_{35}, which was statistically at par with P_{70} (64.99 mg/100 g). Whereas, the minimum (63.95 mg/100 g) was observed in P_{105}, which was significantly lower than rest of P levels. However, K had the direct relationship with ascorbic acid content. The maximum ascorbic acid content (65.80 mg/100 g) was found in K_{150}, which was significantly higher than K_{100} (64.95 mg/100 g) and K_{50} (63.71 mg/100 g).

In case of NxP interaction, $N_{50}P_{35}$ registered the maximum ascorbic acid content (66.45 mg/100 g), which was statistically at par with $N_{150}P_{35}$ (65.16 mg/100 g) and $N_{50}P_{70}$ (66.23 mg/100 g). While the minimum ascorbic acid contents (63.23 mg/100 g) was found in $N_{150}P_{105}$, which was statistically at par with $N_{150}P_{70}$, $N_{100}P_{105}$ and $N_{100}P_{70}$. However, in NxK interaction, $N_{50}K_{150}$ registered the maximum ascorbic acid (68.09 mg/100 g), which was significantly superior to all other combinations of NxK. The minimum ascorbic acid contents (63.63 mg/100 g) was found in $N_{150}K_{50}$, which was statistically at par with $N_{150}K_{150}$, $N_{150}K_{100}$, $N_{100}K_{100}$, $N_{100}K_{50}$ and $N_{50}K_{50}$. In case of PxK interaction, the maximum ascorbic acid content (67.13 mg/100 g) was found in $P_{35}K_{150}$, which was statistically at par with $P_{70}K_{150}$ (66.74 mg/100 g). Whereas, the minimum ascorbic acid (63.18 mg/100 g) was found in $P_{105}K_{50}$, which was statistically at par with $P_{105}K_{150}$, $P_{70}K_{50}$ and $P_{35}K_{50}$.

In different combinations of N, P and K, $N_{50}P_{70}K_{150}$ recorded the maximum ascorbic acid content (69.93 mg/100 g), which was statistically at par with $N_{50}P_{35}K_{150}$ (68.74 mg/100 g). The minimum ascorbic acid content (62.36 mg/100 g) was found in $N_{150}P_{105}K_{150}$, which was statistically at par with $N_{150}P_{35}K_{50}$, $N_{150}P_{70}K_{150}$, $N_{150}P_{70}K_{100}$, $N_{150}P_{70}K_{50}$, $N_{150}P_{105}K_{50}$, $N_{100}P_{105}K_{150}$, $N_{100}P_{105}K_{50}$, $N_{100}P_{70}K_{100}$, $N_{100}P_{70}K_{50}$, $N_{100}P_{35}K_{100}$, $N_{100}P_{35}K_{50}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{50}$ and $N_{50}P_{35}K_{50}$.

4.5 EFFECT OF N, P AND K FERTILIZERS ON LEAF NUTRIENT STATUS

The effect of NPK fertilizers on leaf nutrient status of kiwifruit cv. Allison are presented as under:

4.5.1 Nitrogen

The data pertaining to the effect of NPK fertilizers on leaf N status is presented in Table 18. The perusal of data reveals that increasing level of N showed a direct relationship with leaf N content. The highest leaf N (2.62%) was recorded in N_{150}, which was significantly higher than N_{100} (2.52% N) and N_{50} (2.11% N). In case of P, the maximum leaf content was recorded in P_{35} (2.47%), which was statistically at par with P_{70} (2.45%). However, the minimum leaf N content (2.32%) was recorded in P_{105}, which was significantly lower than other levels of P. In case of K, K_{50} recorded

Table 17. Main and interaction effect of NPK fertilizers on ascorbic acid content (mg/100 g fruit pulp)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	66.45	66.41	64.98	65.95	63.78	65.97	68.09
N_{100}	64.96	64.26	63.64	64.28	63.72	63.85	65.28
N_{150}	65.16	64.31	63.23	64.23	63.63	65.03	64.03
Mean	65.52	64.99	63.95		63.71	64.95	65.80

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	64.33	65.11	67.13
P_{70}	63.62	64.62	66.74
P_{105}	63.18	65.13	63.54

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	64.20	66.41	68.74	63.41	65.88	69.93	63.72	65.61	65.61
N_{100}	64.26	63.29	67.32	63.45	63.45	65.88	63.45	64.82	62.64
N_{150}	64.53	65.61	65.34	63.99	64.53	64.40	62.37	64.95	62.36

$CD_{0.05}$

N = 0.82 NxK = 1.41
P = 0.82 PxK = 1.41
K = 0.82 NxPxK = 2.45
NxP = 1.41

Table 18. Main and interaction effect of NPK fertilizers on per cent leaf N content

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	2.14	2.12	2.05	2.11	2.21	2.15	1.96
N_{100}	2.61	2.57	2.37	2.52	2.85	2.61	2.09
N_{150}	2.67	2.66	2.54	2.62	2.84	2.68	2.35
Mean	2.47	2.45	2.32		2.63	2.48	2.13

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	2.64	2.61	2.16
P_{70}	2.61	2.59	2.16
P_{105}	2.64	2.24	2.08

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	2.23	2.20	1.98	2.20	2.20	1.98	2.21	2.05	1.90
N_{100}	2.87	2.83	2.13	2.82	2.78	2.12	2.86	2.22	2.02
N_{150}	2.84	2.81	2.37	2.82	2.78	2.38	2.85	2.45	2.31

$CD_{0.05}$

N = 0.02
P = 0.02
K = 0.02
NxP = 0.03
NxK = 0.03
PxK = 0.03
NxPxK = 0.06

the maximum leaf N content (2.63%), which was significantly higher than K_{100} (2.48%) and K_{150} (2.13%). Similarly, K_{100} tended to accumulate significantly higher leaf N content than K_{150}.

The different interactions were also found significant. In NxP interaction, the maximum leaf N content (2.67%) was recorded in $N_{150}P_{35}$, which was statistically at par with $N_{150}P_{70}$. The minimum leaf N content (2.05%) was observed in $N_{50}P_{105}$, which was significantly lower than all other combinations of NxP. In NxK interaction, the maximum leaf N content (2.85%) was recorded in $N_{100}K_{50}$, which was statistically at par with $N_{150}K_{50}$ (2.84%). The minimum leaf N content (1.96%) was observed in $N_{50}K_{150}$, which was significantly lower than rest of NxK combinations. In case of PxK interaction, the maximum leaf N content (2.64%) was recorded in $P_{35}K_{50}$ and $P_{105}K_{50}$, which was statistically at par with $P_{70}K_{50}$ and $P_{35}K_{100}$. However, the minimum leaf N content (2.08%) was observed in $P_{105}K_{150}$.

In case of NxPxK interaction, $N_{100}P_{35}K_{50}$ recorded the maximum leaf N content (2.87%), which was statistically at par with $N_{150}P_{105}K_{50}$, $N_{150}P_{70}K_{50}$, $N_{150}P_{35}K_{100}$, $N_{150}P_{35}K_{50}$, $N_{100}P_{105}K_{50}$, $N_{100}P_{70}K_{50}$ and $N_{100}P_{35}K_{100}$. The minimum leaf N content (1.90%) was observed in $N_{50}P_{105}K_{150}$, which was significantly lower than all other combinations of NxPxK.

4.5.2 Phosphorus

The P content of the leaves decreased with the increasing levels of N, while P levels showed direct relationship with leaf P content (Table 19). In case of N, N_{50} recorded the maximum leaf P content of 0.282 per cent, which was significantly higher than N_{100} (0.275%) and N_{150} (0.227%). In case of P levels, P_{105} registered the maximum leaf P content (0.269%), which was statistically at par with P_{70} (0.267%). However, the minimum leaf P content (0.247%) was recorded in P_{35}. In case of K, lowest level of K (K_{50}), showed the maximum leaf P content (0.294%), which was significantly higher than other K levels. The minimum leaf P contents was recorded in K_{150} (0.235%), which was also significantly lower than rest of K levels.

In case of NxP interaction, the maximum leaf P content (0.295%) was recorded in $N_{50}P_{105}$, which was statistically at par with $N_{100}P_{105}$ (0.286%). The minimum leaf P content (0.216%) was recorded in $N_{150}P_{35}$, followed in $N_{150}P_{105}$. These two treatments were statistically at par with each other in respect to leaf P content. In NxK interaction, $N_{50}K_{50}$ recorded the maximum leaf P content (0.335%), which was significantly higher than all other combinations of NxK. The minimum leaf P content (0.219%) was observed in $N_{150}K_{100}$, which was statistically at par with $N_{150}K_{50}$ (0.225%). In case of PxK interaction, $P_{105}K_{50}$ recorded the maximum leaf P content (0.300%), which was at par with $P_{70}K_{50}$ (0.295%). The minimum leaf P content (0.224%) was observed in $P_{35}K_{150}$, which was statistically at par with $P_{35}K_{100}$ (0.232%).

In case of three factor interaction i.e. NxPxK, the maximum leaf P content (0.351%) was recorded in $N_{50}P_{105}K_{50}$, which was significantly higher than all other combinations of NxPxK. However, the minimum leaf P content (0.213%) was recorded in $N_{150}P_{35}K_{100}$, which was statistically at par with $N_{150}P_{35}K_{50}$, $N_{150}P_{35}K_{150}$, $N_{150}P_{70}K_{100}$, $N_{150}P_{105}K_{150}$, $N_{150}P_{105}K_{50}$, $N_{150}P_{105}K_{100}$, $N_{100}P_{70}K_{150}$, $N_{100}P_{35}K_{150}$ and $N_{50}P_{35}K_{150}$.

4.5.3 Potassium

The data on the effect of NPK fertilizers on leaf K status is given in Table 20. In case of N, the maximum leaf K content (2.022%) was recorded in N_{50}, which was significantly higher than other levels of N. The minimum leaf K content was recorded in N_{150} (1.476%), which was significantly lower than all other levels of N. Among the different P levels, P_{35} recorded the highest leaf K content (1.849%), which was statistically at par with P_{70} (1.836%), while the significantly lowest leaf P content (1.755%) was recorded in P_{105}. In case of K, K_{150} registered the maximum leaf K content (2.016%), which was statistically at par with K_{100} (1.960%). The minimum leaf K content was recorded in K_{50} (1.464%), which was significantly lower than all other levels of K.

In case of NxP interaction, the maximum leaf K content (2.043%) was recorded in $N_{50}P_{35}$, which was statistically at par with $N_{100}P_{35}$, $N_{50}P_{105}$, $N_{100}P_{70}$ and $N_{50}P_{70}$. The minimum leaf K content (1.423%) was observed in $N_{150}P_{105}$, which was

Table 19. Main and interaction effect of NPK fertilizers on per cent leaf P content

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	0.267	0.283	0.295	0.282	0.335	0.273	0.237
N_{100}	0.258	0.279	0.286	0.275	0.321	0.273	0.231
N_{150}	0.216	0.239	0.226	0.227	0.225	0.219	0.237
Mean	0.247	0.267	0.269		0.294	0.255	0.235

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	0.286	0.232	0.224
P_{70}	0.295	0.264	0.243
P_{105}	0.300	0.269	0.238

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	0.325	0.245	0.232	0.330	0.286	0.233	0.351	0.288	0.246
N_{100}	0.314	0.237	0.223	0.322	0.284	0.232	0.326	0.296	0.237
N_{150}	0.218	0.213	0.216	0.232	0.222	0.263	0.225	0.222	0.231

$CD_{0.05}$

N = 0.006		NxK = 0.011	
P = 0.006		PxK = 0.011	
K = 0.006		NxPxK = 0.019	
NxP = 0.011			

Table 20. Main and interaction effect of NPK fertilizers on per cent leaf K content

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	2.043	2.030	1.992	2.022	1.553	2.274	2.238
N_{100}	2.004	1.972	1.850	1.942	1.493	2.065	2.268
N_{150}	1.499	1.506	1.423	1.476	1.346	1.540	1.542
Mean	1.849	1.836	1.755		1.464	1.960	2.016

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	1.467	2.002	2.077
P_{70}	1.527	1.944	2.038
P_{105}	1.398	1.933	1.933

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	1.560	2.330	2.239	1.583	2.239	2.269	1.516	2.253	2.205
N_{100}	1.425	2.136	2.451	1.566	2.052	2.298	1.488	2.007	2.054
N_{150}	1.417	1.540	1.541	1.432	1.540	1.547	1.191	1.540	1.539

$CD_{0.05}$

N = 0.060　　NxK = 0.104
P = 0.060　　PxK = 0.104
K = 0.060　　NxPxK = 0.181
NxP = 0.104

statistically at par with $N_{150}P_{35}$ and $N_{150}P_{70}$. In case of NxK interaction, $N_{50}K_{100}$ registered the highest leaf K content (2.274%), which was statistically at par with $N_{50}K_{150}$ and $N_{100}K_{150}$. However, the lowest leaf K content (1.346%) was recorded in $N_{150}K_{50}$. In case of PxK interaction, the maximum leaf K content (2.077%) was recorded in $P_{35}K_{150}$, which was statistically at par with $P_{70}K_{150}$ and $P_{35}K_{100}$. The minimum leaf K content (1.398%) was recorded in $P_{105}K_{50}$, which was at par with $P_{35}K_{50}$ (1.467%).

In case of NxPxK interaction, the maximum leaf K content (2.451%) was recorded in $N_{100}P_{35}K_{150}$, which was statistically at par with $N_{100}P_{70}K_{150}$ and $N_{50}P_{35}K_{100}$. The minimum leaf K content (1.191%) was observed in $N_{150}P_{105}K_{50}$, which was significantly lower than rest of NxPxK combinations.

4.5.4 Calcium

The data pertaining to the effect of NPK fertilizers on leaf Ca status is presented in Table 21. In case of N, maximum leaf Ca content (3.417%) was recorded in N_{150}, which was statistically at par with N_{100} (3.375%). The minimum leaf Ca content was observed in N_{50} (3.196%), which was significantly lower than all other N levels. However, P levels showed non-significant effect on leaf Ca content. In case of K, the maximum leaf Ca content (3.403%) was recorded in K_{50}, which was significantly higher than K_{100} (3.320%) and K_{150} (3.265%). K_{100} was found statistically at par with K_{150} in respect to leaf Ca content.

In case of NxP interaction, $N_{150}P_{35}$ registered the maximum leaf Ca content (3.454%), which was statistically at par with $N_{150}P_{105}$, $N_{150}P_{70}$, $N_{100}P_{105}$ and $N_{100}P_{70}$. The minimum leaf Ca content was observed in $N_{50}P_{35}$ (3.186%), which was at par with $N_{50}P_{105}$ and $N_{50}P_{70}$. In NxK interaction, the highest leaf Ca content (3.544%) was found in $N_{150}K_{50}$, which was statistically at par with $N_{100}K_{50}$ (3.496%). However, the lowest leaf Ca content (3.152%) was recorded in $N_{50}K_{100}$, which was statistically at par with $N_{50}K_{50}$ and $N_{100}k_{150}$. In case of PxK interaction, $P_{70}K_{50}$ registered the maximum leaf Ca content (3.411%), which was at par with $P_{105}K_{150}$, $P_{105}K_{100}$, $P_{105}K_{50}$, $P_{70}K_{100}$ and $P_{35}K_{50}$. While, the minimum leaf Ca content (3.223%) was found in $P_{70}K_{150}$, which was statistically at par with $P_{105}K_{100}$, $P_{105}K_{150}$, $P_{35}K_{100}$ and $P_{35}K_{150}$.

statistically at par with $N_{150}P_{35}$ and $N_{150}P_{70}$. In case of NxK interaction, $N_{50}K_{100}$ registered the highest leaf K content (2.274%), which was statistically at par with $N_{50}K_{150}$ and $N_{100}K_{150}$. However, the lowest leaf K content (1.346%) was recorded in $N_{150}K_{50}$. In case of PxK interaction, the maximum leaf K content (2.077%) was recorded in $P_{35}K_{150}$, which was statistically at par with $P_{70}K_{150}$ and $P_{35}K_{100}$. The minimum leaf K content (1.398%) was recorded in $P_{105}K_{50}$, which was at par with $P_{35}K_{50}$ (1.467%).

In case of NxPxK interaction, the maximum leaf K content (2.451%) was recorded in $N_{100}P_{35}K_{150}$, which was statistically at par with $N_{100}P_{70}K_{150}$ and $N_{50}P_{35}K_{100}$. The minimum leaf K content (1.191%) was observed in $N_{150}P_{105}K_{50}$, which was significantly lower than rest of NxPxK combinations.

4.5.4 Calcium

The data pertaining to the effect of NPK fertilizers on leaf Ca status is presented in Table 21. In case of N, maximum leaf Ca content (3.417%) was recorded in N_{150}, which was statistically at par with N_{100} (3.375%). The minimum leaf Ca content was observed in N_{50} (3.196%), which was significantly lower than all other N levels. However, P levels showed non-significant effect on leaf Ca content. In case of K, the maximum leaf Ca content (3.403%) was recorded in K_{50}, which was significantly higher than K_{100} (3.320%) and K_{150} (3.265%). K_{100} was found statistically at par with K_{150} in respect to leaf Ca content.

In case of NxP interaction, $N_{150}P_{35}$ registered the maximum leaf Ca content (3.454%), which was statistically at par with $N_{150}P_{105}$, $N_{150}P_{70}$, $N_{100}P_{105}$ and $N_{100}P_{70}$. The minimum leaf Ca content was observed in $N_{50}P_{35}$ (3.186%), which was at par with $N_{50}P_{105}$ and $N_{50}P_{70}$. In NxK interaction, the highest leaf Ca content (3.544%) was found in $N_{150}K_{50}$, which was statistically at par with $N_{100}K_{50}$ (3.496%). However, the lowest leaf Ca content (3.152%) was recorded in $N_{50}K_{100}$, which was statistically at par with $N_{50}K_{50}$ and $N_{100}k_{150}$. In case of PxK interaction, $P_{70}K_{50}$ registered the maximum leaf Ca content (3.411%), which was at par with $P_{105}K_{150}$, $P_{105}K_{100}$, $P_{105}K_{50}$, $P_{70}K_{100}$ and $P_{35}K_{50}$. While, the minimum leaf Ca content (3.223%) was found in $P_{70}K_{150}$, which was statistically at par with $P_{105}K_{100}$, $P_{105}K_{150}$, $P_{35}K_{100}$ and $P_{35}K_{120}$.

In NxPxK interaction, the highest leaf Ca content (3.619%) was recorded in $N_{150}P_{35}K_{50}$, which was statistically at par with $N_{150}P_{35}K_{100}$, $N_{150}P_{70}K_{50}$, $N_{150}P_{70}K_{100}$, $N_{150}P_{105}K_{50}$, $N_{100}P_{105}K_{50}$, $N_{100}P_{70}K_{50}$ and $N_{100}P_{35}K_{50}$. The lowest leaf Ca content (3.071%) was recorded in $N_{50}P_{35}K_{100}$, which was statistically at par with $N_{150}P_{70}K_{150}$, $N_{100}P_{70}K_{150}$, $N_{100}P_{35}K_{150}$, $N_{50}P_{105}K_{150}$, $N_{50}P_{105}K_{100}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$, $N_{50}P_{70}K_{50}$ and $N_{50}P_{35}K_{50}$.

4.5.5 Magnesium

The data on the effect of NPK fertilizers on leaf Mg status is presented in Table 22. In case of N, the maximum leaf Mg content (0.868%) was recorded in N_{150}, which was significantly higher than all other levels of N. The minimum leaf Mg content (0.827%) was observed in N_{50}, which was also significantly lower than all other levels of N. In P, P_{35} recorded the maximum leaf Mg content (0.856%), which was statistically at par with P_{70} (0.855%). The minimum leaf Mg content was recorded in P_{105} (0.842%). In case of K, the maximum leaf Mg content (0.855%) was recorded in K_{50}, which was statistically at par with K_{100} (0.853%). However, the minimum leaf Mg content was found in K_{150} (0.845%).

In case of NxP interaction, $N_{150}P_{70}$ registered the highest leaf Mg content (0.874%), which was statistically at par with $N_{150}P_{35}$ (0.873%). The lowest leaf Mg content (0.818%) was recorded in $N_{50}P_{105}$, which was significantly lower than other combinations of NxP. In case of NxK interaction, the maximum leaf Mg content (0.878%) was recorded in $N_{150}K_{50}$, which was found to be statistically at par with $N_{150}K_{100}$ and $N_{100}K_{50}$. The minimum leaf Mg content (0.818%) was found in $N_{50}K_{50}$, which was statistically at par with $N_{50}K_{150}$ (0.820%). Similarly in PxK interaction, $P_{35}K_{100}$ registered the maximum leaf Mg content (0.866%), which was statistically at par with $P_{70}K_{100}$ and $P_{35}K_{50}$. The minimum leaf Mg content (0.833%) was observed in $P_{105}K_{100}$, which was at par with $P_{35}K_{150}$ (0.837%).

In case of three factor interaction i.e. NxPxK, the combination of $N_{150}P_{35}K_{100}$ recorded the highest leaf Mg content (0.894%), which was statistically at par with

Table 21. Main and interaction effect of NPK fertilizers on per cent leaf Ca content

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	3.186	3.189	3.212	3.196	3.171	3.152	3.264
N_{100}	3.347	3.372	3.405	3.375	3.496	3.393	3.235
N_{150}	3.454	3.407	3.392	3.417	3.544	3.414	3.294
Mean	3.329	3.323	3.336		3.403	3.320	3.265

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	3.409	3.307	3.271
P_{70}	3.411	3.334	3.223
P_{105}	3.390	3.319	3.300

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	3.145	3.071	3.343	3.183	3.179	3.205	3.184	3.208	3.244
N_{100}	3.463	3.389	3.190	3.528	3.372	3.217	3.497	3.419	3.299
N_{150}	3.619	3.461	3.281	3.523	3.452	3.246	3.489	3.331	3.356

$CD_{0.05}$

N = 0.059 NxK = 0.102
P = NS PxK = 0.102
K = 0.059 NxPxK = 0.177
NxP = 0.102

Table 22. Main and interaction effect of NPK fertilizers on per cent leaf Mg content

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	0.831	0.831	0.818	0.827	0.818	0.842	0.820
N_{100}	0.863	0.861	0.851	0.858	0.870	0.846	0.857
N_{150}	0.873	0.874	0.858	0.868	0.878	0.870	0.857
Mean	0.856	0.855	0.842		0.855	0.853	0.845

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	0.864	0.866	0.837
P_{70}	0.855	0.859	0.852
P_{105}	0.848	0.833	0.845

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	0.842	0.843	0.809	0.818	0.848	0.826	0.795	0.835	0.824
N_{100}	0.869	0.861	0.859	0.873	0.848	0.860	0.869	0.830	0.853
N_{150}	0.881	0.894	0.843	0.873	0.881	0.869	0.879	0.835	0.859

$CD_{0.05}$

N = 0.005
P = 0.005
K = 0.005
NxP = 0.010
NxK = 0.010
PxK = 0.010
NxPxK = 0.016

$N_{150}P_{35}K_{50}$, $N_{150}P_{70}K_{100}$ and $N_{150}P_{105}K_{50}$. The minimum leaf Mg content (0.795%) was observed in $N_{50}P_{105}K_{50}$, which was at par with $N_{50}P_{35}K_{150}$ (0.809%).

4.5.6 Zinc

The data on the effect of NPK fertilizers on leaf Zn status is presented in Table 23. A perusal of data reveals that increasing levels of N, P and K showed direct relationship with leaf Zn content. In case of N, the maximum leaf Zn content (94.67 ppm) was recorded in N_{150}, which was significantly higher than other levels of N. The minimum leaf Zn content (87.33 ppm) was observed in N_{50}, which was significantly less than other N levels. Among the different P levels, P_{105} recorded the maximum leaf Zn content (92.37 ppm), which was statistically at par with P_{70} (91.33 ppm). While, the minimum leaf Zn content (90.41 ppm) was found in P_{35}, which was statistically at par with P_{70} (91.33 ppm). In case of K, the maximum leaf Zn content (92.07 ppm) was recorded in K_{150}, which was at par with K_{100} (91.96 ppm) and the minimum Zn content (90.07 ppm) was found in K_{50}. In case of NxP, the maximum leaf Zn content (96.00 ppm) was recorded in $N_{150}P_{105}$, which was significantly higher than other combinations of NxP. The minimum leaf Zn content (85.67 ppm) was observed in $N_{50}P_{35}$, which was also significantly lower than rest of NxP combinations. Among the NxK interaction, $N_{150}K_{100}$ registered the highest leaf Zn content (96.22 ppm), which was statistically at par with $N_{150}K_{150}$ and $N_{100}K_{100}$. The lowest leaf Zn content (83.33 ppm) was recorded in $N_{50}K_{50}$, which was statistically at par with $N_{50}K_{100}$ (84.78 ppm). Similarly, in PxK combinations, the maximum leaf Zn content (94.78 ppm) was observed in $P_{35}K_{150}$, which was statistically at par with $P_{105}K_{50}$. The minimum leaf Zn content (85.67 ppm) was recorded in $P_{35}K_{50}$, which was significantly lower as compared to all other combinations of PxK.

In NxPxK interaction, the maximum leaf Zn content (97.00 ppm) was registered in $N_{150}P_{105}K_{100}$, which was statistically at par with $N_{150}P_{105}K_{150}$, N[illegible], $N_{150}P_{70}K_{100}$, $N_{150}P_{35}K_{150}$, $N_{150}P_{35}K_{100}$, $N_{100}P_{105}K_{150}$, $N_{100}P_{70}K_{100}$ and $N_{100}P_{35}K_{150}$. However, the minimum leaf Zn content (82.00 ppm) was observed in $N_{50}P_{35}K_{50}$, which was statistically at par with $N_{50}P_{70}K_{100}$ and $N_{50}P_{35}K_{100}$.

4.5.7 Iron

The data pertaining to the effect of NPK fertilizers on leaf Fe status is presented in Table 24. In case of N, the maximum leaf Fe content (327.0 ppm) was recorded in N_{150}, which was significantly higher than other N levels. The minimum leaf Fe content (310.0 ppm) was observed in N_{50}, which was statistically lower than N_{150} and N_{100}. In P, the maximum leaf Fe content (327.3 ppm) was observed in P_{70}, which was significantly higher than P_{105} (317.0 ppm) and P_{35} (311.6 ppm). In case of K, K_{50} registered the highest leaf Fe content (232.9 ppm), which was significantly higher than other K levels. The lowest leaf Fe content (309.3 ppm) was observed in K_{150}, which was significantly lower than K_{50} and K_{100}.

In two factor interaction of NxP, the maximum leaf Fe content was recorded in $N_{100}P_{70}$ (336.9 ppm), which was statistically at par with $N_{150}P_{105}$ (329.6 ppm). The minimum leaf Fe content (305.7 ppm) was observed in $N_{100}P_{35}$, which was statistically at par with $N_{50}P_{105}$ and $N_{50}P_{35}$. In case of NxK interaction, the highest leaf Fe content (343.8 ppm) was recorded in $N_{150}K_{50}$, which was statistically at par with $N_{100}K_{50}$ (336.7 ppm). The lowest leaf Fe content (305.6 ppm) was observed in $N_{50}K_{150}$, which was statistically at par with $N_{50}K_{100}$, $N_{100}K_{150}$, $N_{150}K_{150}$ and $N_{100}K_{100}$. In case of PxK combinations, $P_{70}K_{50}$ registered the maximum leaf Fe content (344.1 ppm), which was significantly higher than other combinations of PxK. The minimum leaf Fe content (305.4 ppm) was recorded in $P_{105}K_{150}$, which was statistically at par with $P_{105}K_{100}$, $P_{35}K_{100}$ and $P_{35}K_{150}$.

In case of NxPxK interaction, $N_{100}P_{70}K_{50}$ registered the maximum leaf Fe content (349.0 ppm), which was statistically at par with $N_{150}P_{105}K_{50}$, $N_{150}P_{70}K_{50}$, $N_{150}P_{35}K_{50}$, $N_{100}P_{105}K_{50}$ and $N_{50}P_{70}K_{50}$. The minimum leaf Fe content (294.0 ppm) was recorded in $N_{100}P_{35}K_{100}$, which was statistically at par with $N_{150}P_{35}K_{150}$, $N_{100}P_{105}K_{150}$, $N_{100}P_{105}K_{100}$, $N_{50}P_{105}K_{150}$, $N_{50}P_{70}K_{100}$ and $N_{50}P_{35}K_{150}$.

4.5.8 Copper

The data pertaining to the effect of NPK fertilizers on leaf Cu content is presented in Table 25. Among the different levels of N, the highest level of N i.e. N_{150}

Table 23. Main and interaction effect of NPK fertilizers on leaf Zn content (ppm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	85.67	87.89	88.44	87.33	83.33	84.78	88.89
N_{100}	91.44	92.22	92.67	92.11	89.56	94.89	91.89
N_{150}	94.11	93.89	96.00	94.67	92.33	96.22	95.44
Mean	90.41	91.33	92.37		90.07	91.96	92.07

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	85.67	90.78	94.78
P_{70}	91.22	92.00	90.78
P_{105}	93.33	93.11	90.67

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	82.00	82.67	92.33	91.67	84.67	87.33	91.33	87.00	87.00
N_{100}	85.00	94.00	95.33	90.00	95.33	91.33	93.67	95.33	89.00
N_{150}	90.00	95.67	96.67	92.00	96.00	93.67	95.00	97.00	96.00

$CD_{0.05}$

N = 0.92
P = 0.92
K = 0.92
NxP = 1.58
NxK = 1.58
PxK = 1.58
NxPxK = 2.75

Table 24. Main and interaction effect of NPK fertilizers on leaf Fe content (ppm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	306.7	316.2	307.1	310.0	318.1	306.3	305.6
N_{100}	305.7	336.9	314.4	319.0	336.7	309.9	310.4
N_{150}	322.6	328.8	329.6	327.0	343.8	325.1	312.0
Mean	311.6	327.3	317.0		332.9	313.8	309.3

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	320.0	308.2	306.7
P_{70}	344.1	321.9	315.9
P_{105}	334.4	311.2	305.4

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	307.3	308.7	304.0	337.3	303.0	308.3	309.7	307.3	304.3
N_{100}	312.7	294.0	310.3	349.0	335.3	326.3	348.3	300.3	294.7
N_{150}	340.0	322.0	305.7	346.0	327.3	313.0	345.0	326.0	317.3

$CD_{0.05}$

N = 4.31
P = 4.31
K = 4.31
NxP = 7.45
NxK = 7.45
PxK = 7.45
NxPxK = 12.91

Table 25. Main and interaction effect of NPK fertilizers on leaf Cu content (ppm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	20.67	20.56	20.11	20.44	20.56	20.56	20.22
N_{100}	23.56	24.78	24.33	24.22	23.78	25.00	23.89
N_{150}	25.44	26.56	25.44	25.81	25.44	26.22	25.78
Mean	23.22	23.96	23.30		23.26	23.93	23.30

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	22.67	23.67	23.33
P_{70}	23.89	24.33	23.67
P_{105}	23.22	23.78	22.89

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	19.67	22.00	20.33	21.67	20.33	19.67	20.33	19.33	20.67
N_{100}	20.67	24.00	24.00	24.67	25.67	24.00	24.00	25.33	23.67
N_{150}	25.67	25.00	25.67	25.33	27.00	27.33	25.33	26.67	24.33

$CD_{0.05}$

N = 0.82
P = NS
K = NS
NxP = 1.41
NxK = 1.41
PxK = 1.41
NxPxK = 2.46

recorded the maximum leaf Cu content (25.81 ppm), which was significantly higher than N_{100} (24.22 ppm) and N_{50} (20.44 ppm). Similarly, N_{50} was significantly lower than N_{100} and N_{150}. However, the effect of P and K on leaf Cu content was found to be non-significant.

In case of NxP interaction, the maximum leaf Cu content (26.56 ppm) was observed in $N_{150}P_{70}$, which was statistically at par with $N_{150}P_{105}$ and $N_{150}P_{35}$. However, the minimum leaf Cu content (20.11 ppm) was recorded in $N_{50}P_{105}$, which was statistically at par with $N_{50}P_{70}$ and $N_{50}P_{35}$. In, NxK interaction, $N_{150}K_{100}$ registered the maximum leaf Cu content (26.22 ppm), which was statistically at par with $N_{150}K_{50}$, $N_{150}K_{150}$ and $N_{100}K_{100}$. The minimum leaf Cu content (20.22 ppm) was registered in $N_{50}K_{150}$, which was at par with $N_{50}K_{100}$ and $N_{50}K_{50}$. Similarly, in PxK interaction, the maximum leaf Cu content (24.33 ppm) was observed in $P_{70}K_{100}$, which was statistically at par with $P_{105}K_{100}$, $P_{105}K_{50}$, $P_{70}K_{50}$, $P_{70}K_{150}$, $P_{35}K_{150}$ and $P_{35}K_{100}$. While, the minimum leaf Cu content (22.67 ppm) was observed in $P_{35}K_{50}$.

In case of NxPxK interaction, the highest leaf Cu content (27.33 ppm) was recorded in $N_{150}P_{70}K_{150}$, which was statistically at par with $N_{100}P_{70}K_{100}$, $N_{150}P_{105}K_{50}$, $N_{150}P_{70}K_{100}$, $N_{150}P_{70}K_{50}$, $N_{150}P_{35}K_{150}$, $N_{150}P_{35}K_{100}$, $N_{150}P_{35}K_{50}$, $N_{100}P_{105}K_{100}$ and $N_{150}P_{105}K_{100}$. The lowest leaf Cu content (19.33 ppm) was observed in $N_{50}P_{105}K_{100}$, which was statistically at par with $N_{50}P_{105}K_{150}$, $N_{50}P_{105}K_{50}$, $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$, $N_{50}P_{70}K_{50}$, $N_{50}P_{35}K_{150}$, $N_{50}P_{35}K_{50}$ and $N_{100}P_{35}K1_{50}$.

4.5.9 Manganese

The data on the effect of NPK fertilizers on the leaf Mn content is presented in Table 26. It is evident from the data that increasing dose of N had direct relationship with leaf Mn content. The maximum leaf Mn content (46.19 ppm) was recorded in N_{150}, which was significantly higher than other levels of N. The minimum leaf Mn content was recorded in N_{50} (44.42 ppm), which was statistically at par with N_{100} (44.59 ppm). In case of P, the maximum leaf Mn content (46.52 ppm) was recorded in P_{105}, which was significantly higher than all other P levels. The minimum leaf Mn content of 44.19 ppm was observed in P_{70}, which was statistically at par with P_{35}

(44.30 ppm). In K, K_{100} registered the maximum leaf Mn content (46.41 ppm), which was significantly higher than K_{150} (45.22 ppm) and K_{50} (43.37 ppm). Similarly K_{150} was significantly superior than K_{50} in respect to leaf Mn content.

In case of NxP interaction, the maximum leaf Mn content (51.44 ppm) was recorded in $N_{150}P_{105}$, which was significantly higher than all other combinations of NxP. The minimum leaf Mn content (42.78 ppm) was observed in $N_{150}P_{35}$, which was statistically at par with $N_{50}P_{105}$ (43.78 ppm). In NxK interaction, $N_{150}K_{150}$ registered the highest leaf Mn content (48.11 ppm), which was at par with $N_{50}K_{100}$ (47.67 ppm). While, the lowest leaf Mn content (40.44 ppm) was observed in $N_{50}K_{50}$. In case of PxK interaction, the maximum leaf Mn content (48.00 ppm) was recorded in $P_{105}K_{150}$ and $P_{70}K_{100}$, which was significantly higher than all other combinations of PxK. The minimum leaf Mn content (41.78 ppm) was observed in $P_{35}K_{50}$, which was statistically at par with $P_{70}K_{50}$ and $P_{70}K_{150}$.

In case of three factor interaction i.e. NxPxK, the maximum leaf Mn content (54.33 ppm) was recorded in $N_{150}P_{105}K_{150}$, which was significantly higher than other combinations of NxPxK. The minimum leaf Mn content (39.33 ppm) was recorded in $N_{150}P_{35}K_{50}$ and $N_{50}P_{70}K_{50}$, which was statistically at par with $N_{50}P_{105}K_{50}$.

4.6.3 Available soil nitrogen

The data on the effect of NPK fertilizers on available nitrogen content in the soil is presented in Table 27. It is apparent from the data presented in the Table 27, that soil application of N, P and K fertilizers exerted an appreciable effect on available N content. Nitrogen content in the soil was found to be highest (365.4 kg/ha) with the soil application of N_{150} level, which was significantly higher than the other N levels. While, the lowest nitrogen content in soil was recorded in N_{50} (362.3 kg/ha), which was significantly lower than other levels of N. In case of P, higher level of P (P_{105}) recorded 365.3 kg N/ha in the soil, which was significantly higher than other P levels. While, minimum N content in soil was found in P_{35} (363.5 kg/ha), which was statistically at par with P_{70} (363.9 kg/ha). Similarly, K_{150} recorded the maximum N content (365.7 kg/ha) in the soil, which was significantly higher than

Table 26. Main and interaction effect of NPK fertilizers on leaf Mn content (ppm)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	44.89	44.00	43.78	44.22	40.44	47.67	44.56
N_{100}	45.22	44.22	44.33	44.59	45.33	45.44	43.00
N_{150}	42.78	44.33	51.44	46.19	44.33	46.11	48.11
Mean	44.30	44.19	46.52		43.37	46.41	45.22

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	41.78	46.00	45.11
P_{70}	42.00	48.00	42.56
P_{105}	46.33	45.22	48.00

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	42.33	48.33	44.00	39.33	50.33	42.33	39.67	44.33	47.33
N_{100}	43.67	46.67	45.33	43.67	47.67	41.33	48.67	42.00	42.33
N_{150}	39.33	43.00	46.00	43.00	46.00	44.00	50.67	49.33	54.33

$CD_{0.05}$

N = 0.66
P = 0.66
K = 0.66
NxP = 1.14
NxK = 1.14
PxK = 1.14
NxPxK = 1.98

Table 27. Main and interaction effect of NPK fertilizers on available N status (kg/ha)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	362.1	361.7	363.1	362.3	361.5	362.1	363.4
N_{100}	364.0	364.8	366.0	364.9	364.4	364.0	366.5
N_{150}	364.3	365.2	366.6	365.4	364.9	364.1	367.3
Mean	363.5	363.9	365.3		363.6	363.4	365.7

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	363.0	363.0	364.4
P_{70}	363.5	363.1	365.2
P_{105}	364.2	364.1	367.5

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	361.4	362.0	362.8	361.0	361.8	362.3	361.9	362.4	365.1
N_{100}	363.5	363.4	364.9	364.4	363.7	366.4	365.2	364.9	368.1
N_{150}	364.1	363.4	365.5	365.1	363.7	366.9	365.4	365.1	369.4

$CD_{0.05}$

N = 0.45
P = 0.45
K = 0.45
NxP = 0.79
NxK = 0.79
PxK = 0.79
NxPxK = 1.37

other levels and minimum N content was recorded in K_{100} (363.4 kg/ha), which was statistically at par with K_{50} (363.6 kg/ha).

Among NxP interaction, $N_{150}P_{105}$ recorded the maximum content of N (366.6 kg/ha), which was statistically at par with $N_{100}P_{105}$ (366.0 kg/ha), while the minimum was recorded in $N_{50}P_{70}$ (361.7 kg/ha), which was statistically at par with $N_{50}P_{35}$ (362.1 kg/ha). In case of NxK interaction, $N_{150}K_{150}$ registered the highest N content in soil (367.3 kg/ha), which was significantly higher than all other NxK combinations. Whereas, lowest N content in soil was recorded in $N_{50}K_{50}$ (361.5 kg/ha), which was at par with $N_{50}K_{100}$ (362.1 kg/ha). Similarly in PxK interaction, the maximum content of N in soil was recorded in $P_{105}K_{150}$ (367.5 kg/ha), which was significantly higher than all other combinations of PxK. While, the minimum N (363.0 kg/ha) was recorded in $P_{35}K_{50}$ and $P_{35}K_{100}$, which was statistically at par with $P_{70}K_{100}$ (363.1 kg/ha) and $P_{70}K_{50}$ (365.5 kg/ha).

In three factor interaction, $N_{150}P_{105}K_{150}$ registered the maximum N content in soil (369.4 kg/ha), which was statistically at par with $N_{100}P_{105}K_{150}$ (368.1 kg/ha). Whereas, minimum N content in soil was recorded in $N_{50}P_{70}K_{50}$ (361.0 kg/ha), which was statistically at par with $N_{50}P_{70}K_{150}$, $N_{50}P_{70}K_{100}$, $N_{50}P_{35}K_{100}$, $N_{50}P_{35}K_{50}$ and $N_{50}P_{105}K_{50}$.

4.6.4 Available soil phosphorus

The data on the main effect of NPK fertilizers on available phosphorus content is presented in Table 28. In case of N, N_{50} registered the highest P content of 39.87 kg/ha in soil, which was statistically at par with N_{100} (39.34 kg/ha), while the lowest was recorded in N_{150} (38.02 kg/ha). In case of P, maximum P content in soil was recorded in P_{105} (45.81 kg/ha), which was significantly higher than all other levels of P. The minimum available P content was recorded in P_{35} (33.21 kg/ha), which was significantly lower than all other levels of P. Among the different levels of K, the maximum P content in soil (40.95 kg/ha) was recorded in K_{100}. While, the minimum was recorded in K_{50} (36.44 kg/ha).

In case of NxP interaction, $N_{50}P_{105}$ recorded the maximum content of P (47.04 kg/ha) in soil, which was statistically at par with $N_{100}P_{105}$ (46.33 kg/ha). However, the minimum P content in soil was found in $N_{150}P_{35}$ (32.78 kg/ha), which was also at par with $N_{100}P_{35}$ (33.11 kg/ha) and $N_{50}P_{35}$ (33.73 kg/ha). Among NxK interaction, the highest P content of 42.12 kg/ha in soil was recorded in $N_{50}K_{100}$, which was statistically at par with $N_{100}K_{100}$ (41.46 kg/ha). While, the lowest P content in soil was found in $N_{150}K_{50}$ (35.70 kg/ha). Similarly in PxK interaction, $P_{105}K_{100}$ registered the maximum P content of 49.79 kg/ha in soil, which was significantly highest than all other PxK combinations. The minimum P content in soil was recorded in $P_{35}K_{50}$ (32.06 kg/ha), which was also significantly lowest than rest of PxK combinations.

Under NxPxK interaction the maximum P content of 52.15 kg/ha in soil was recorded in $N_{50}P_{105}K_{100}$, which was statistically at par with $N_{100}P_{105}K_{100}$. However, the minimum P content in soil was found in $N_{150}P_{35}K_{50}$ (31.65 kg/ha), which was statistically at par with $N_{50}P_{35}K_{50}$, $N_{100}P_{35}K_{150}$, $N_{100}P_{35}K_{50}$ and $N_{150}P_{35}K_{150}$.

4.4.5 Available soil potassium

The data on the effect of NPK fertilizers on available potassium is depicted in Table 29. The perusal of data presented in the table indicate that soil application of N, P and K exerted considerable influence on available potassium content of the soil. Highest available K (293.5 kg/ha) was recorded with N_{150}, which was statistically at par with N_{100} (292.7 kg/ha). While, the lowest K content in soil was found in N_{50} (291.4 kg/ha). However, all the P levels were significantly different. The maximum available K content was recorded in P_{35} (296.0 kg/ha), while the minimum (289.5 kg/ha) was recorded in P_{105}. Similarly, all K levels exhibited significant effect on the K content in the soil. The highest available K content in soil was recorded in K_{150} (305.4 kg/ha). Whereas, the minimum K content was found in K_{50} (280.0 kg/ha).

Under NxP interaction, $N_{150}P_{35}$ registered the maximum available K content (296.9 kg/ha) in the soil, which was statistically at par with $N_{100}P_{35}$ (296.2 kg/ha). Whereas, the minimum K content in the soil was recorded in $N_{50}P_{105}$ (288.3 kg/ha), which was statistically at par with $N_{100}P_{105}$ (289.6 kg/ha). In NxK interaction, $N_{150}K_{150}$ registered the maximum available K content (306.2 kg/ha) in soil, which was statistically at par with $N_{100}K_{150}$ (305.8 kg/ha). The minimum available K content in

Table 28. Main and interaction effect of NPK fertilizers on available P status (kg/ha)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	33.73	38.84	47.04	39.87	36.81	42.12	40.69
N_{100}	33.11	38.59	46.33	39.34	36.80	41.46	39.77
N_{150}	32.78	37.25	44.04	38.02	35.70	39.27	39.09
Mean	33.21	38.23	45.81		36.44	40.95	39.85

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	32.06	34.54	33.02
P_{70}	35.44	38.51	40.73
P_{105}	41.82	49.79	45.80

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	32.42	34.74	34.02	35.77	39.45	41.30	42.23	52.15	46.74
N_{100}	32.10	34.68	32.56	35.79	38.90	41.07	42.52	50.79	45.69
N_{150}	31.65	34.19	32.48	34.76	37.18	39.81	40.70	46.43	44.98

$CD_{0.05}$

N = 0.55
P = 0.55
K = 0.55
NxP = 0.95
NxK = 0.95
PxK = 0.95
NxPxK = 1.64

Table 29. Main and interaction effect of NPK fertilizers on available K status (kg/ha)

a) NxP and NxK interactions

	P_{35}	P_{70}	P_{105}	Mean	K_{50}	K_{100}	K_{150}
N_{50}	294.8	291.2	288.3	291.4	279.2	290.8	304.3
N_{100}	296.2	292.4	289.6	292.7	280.1	292.3	305.8
N_{150}	296.9	293.0	290.6	293.5	280.7	293.6	306.2
Mean	296.0	292.2	289.5		280.0	292.2	305.4

b) PxK interaction

	K_{50}	K_{100}	K_{150}
P_{35}	282.9	294.9	310.1
P_{70}	279.6	292.3	304.8
P_{105}	277.6	289.4	301.4

c) NxPxK interaction

	P_{35}			P_{70}			P_{105}		
	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}	K_{50}	K_{100}	K_{150}
N_{50}	282.3	293.0	309.0	278.3	291.3	304.0	277.0	288.0	300.0
N_{100}	283.0	295.3	310.3	280.0	292.3	305.0	277.3	289.3	302.0
N_{150}	283.3	296.3	311.0	280.3	293.3	305.3	278.3	291.0	302.3

$CD_{0.05}$

N = 0.90 NxK = 1.50
P = 0.90 PxK = 1.50
K = 0.90 NxPxK = 2.60
NxP = 1.50

soil was recorded in $N_{50}K_{50}$ (279.2 kg/ha), which was statistically at par with $N_{150}K_{50}$ (280.7 kg/ha) and $N_{100}K_{50}$ (280.1 kg/ha). However, in PxK interaction, maximum available K content of 310.1 kg/ha was recorded in $P_{35}K_{150}$, which was significantly higher than rest of PxK combinations, while the minimum available K content (277.6 kg/ha) was found in $P_{105}K_{50}$.

In three factor interactions, $N_{150}P_{35}K_{150}$ registered the highest available K content of 311.0 kg/ha in soil, which was statistically at par with $N_{100}P_{35}K_{150}$ (310.3 kg/ha) and $N_{50}P_{35}K_{150}$ (309.0 kg/ha). While, the lowest content of available K (277.0 kg/ha) was recorded in $N_{50}P_{105}K_{50}$, which was statistically at par with $N_{150}P_{105}K_{50}$ (278.3 kg/ha), $N_{100}P_{105}K_{50}$ (277.3 kg/ha) and $N_{50}P_{70}K_{50}$ (278.3 kg/ha).

DISCUSSION

Chapter-5

DISCUSSION

The results obtained in the present investigations on the "Studies on the effect of N, P and K fertilizer levels on growth, yield and quality of kiwifruit cv. Allison" are discussed as under:

5.1 VINE GROWTH AND VIGOUR

Application of different levels of N, P and K fertilizers was found to exert a significant influence on vine growth in terms of trunk girth and shoot growth. Vine growth increased with increase in the level of N. The maximum girth and shoot growth was recorded with highest dose of N i.e. N_{150} and minimum with lowest dose of N i.e. N_{50}. These results are in conformity with those of Costa *et al.* (1997), who reported significant increase in vegetative growth with the increasing nitrogen application from 0 to 450 kg/ha in kiwifruit. The higher level of N increased uptake of N in the plant (Table 18), which increased the chlorophyll content (Ritter, 1956) and rate of photosynthesis (Lysenko *et al.*, 1974), which might have accounted for higher growth of vine grown under higher level of nitrogen. These findings are supported by the earlier reports of Costa *et al.* (1997), who recorded more vegetative growth in kiwifruit due to the increased photosynthetic rate with the increasing levels of N. The various levels of K also showed similar trend in terms of vine growth. The maximum girth and shoot growth was recorded with K_{150} and minimum in K_{50}. Bussi and Defrance (1986) also observed increased growth and vigour with increased level of K in peach. Regarding the P application, no consistent results were obtained and the maximum vine girth was recorded at P_{70}, however, the shoot growth was found to be maximum at P_{105}.

The two and three factor interactions were found significant in terms of vine growth. The maximum vine girth and shoot growth was recorded with $N_{150}P_{105}K_{100}$ treatment combination. The increased growth with the combined application of NPK might be attributed to the cumulative effects of N, P and K, as they play a pivotal role in the metabolic processes in the plant (Nijjar, 1996). These findings are in agreement with the observations made by Smith and Miller (1991), who reported that the application of NPK fertilizers @700 or 1420 kg N, 490 or 1090 kg P and 600 or 1200 kg K/ha increased the vegetative growth and root growth of kiwifruit vines. Higher tree growth with N and K, N and P and N, P and K has also been reported by Bussi and Defrance (1986) in peach and Crespan *et al.* (1999) in grapes.

5.2 YIELD

Significant variations in total yield as well as yield of different grades of fruits was observed in vines subjected to different levels of NPK fertilizers. The yield showed a increasing trend with increase in N application. N_{150} gave the highest total yield and yield of A and B grades fruit, which was statistically at par with N_{100}. However, the lowest total yield and yield of A and B grades fruit was recorded in lowest level of N i.e. N_{50}. The better size and weight of fruits (Tables 8, 9 and 10) in vines which received higher N fertilizer in the present study may account for higher yield. These results are in accordance with those of Testoni *et al.* (1990), who obtained highest yield in kiwifruit with increased N application from 100 kg to 200 kg/ha. Vizzotto *et al.* (1999) observed positive correlation of yield to the rates of N fertilization in kiwifruit. The application of K fertilizer also showed similar trend as in case of N. The maximum total yield and yield of A and B grades fruit was recorded in $K_{[illegible]}$ and minimum in K_{60}. These findings are in conformity with those of Borghi *et al.* (1995), who reported increase in fruit yield from 55.9 to 64.6 kg/ tree in peaches with the increase in K_2O from 100 kg to 200 kg/ha.

The individual effect of P fertilizer showed that the maximum yield was recorded with medium level of P, i.e. P_{70}, which was significantly higher than P_{35} and $P_{[illegible]}$. The highest yield in P_{70} was ascribed due to the better fruit size and weight of fruits with P_{70} as compared to other levels of P. Similar increase in fruit yield of peach under medium P level has also been reported by Bussi *et al.* (1991).

The interaction effects of NPK fertilizers were observed to be significant on both total yield and yield of different grades of fruit. The maximum total yield and yield of A grade fruits was recorded in $N_{100}P_{70}K_{150}$, however, further increase in the dose of N and P i.e. $N_{150}P_{105}K_{150}$ did not show any significant increase in yield as compared to $N_{100}P_{70}K_{150}$. These findings are inconformity with those of Testoni *et al.* (1990), who also obtained highest yield with 200 kg N and 200 kg K_2O/ha in kiwifruit. However, they observed a decrease in yield when dose was increased to 300 kg/ha in kiwifruit. Monastra *et al.* (1995) also recorded highest yield with the application of 150 kg N, 39 kg P_2O_5 and 124 kg K_2O/ha in kiwifruit, they further reported that further increase in NPK fertilizers had no beneficial effect on yield. Increase in yield with combined application of NPK fertilizers have also been reported by Smith and Miller (1991) in kiwifruit and Terra *et al.* (2000) in grapevine. The minimum yield was recorded in the lowest level of NPK i.e. $N_{150}P_{35}K_{50}$. The smaller fruit size and weight (Tables 8, 9 & 10) in the vines receiving $N_{50}P_{35}K_{50}$ fertilizer treatment might have accounted for lower yield in the present study.

5.3 FRUIT QUALITY

5.3.1 Physical characteristics of fruit

Fruit size in terms of length and breadth and fruit weight were significantly increased with the application of NPK fertilizers at various levels. Among N levels, N_{150} resulted in maximum fruit length and diameter as well as fruit weight. However, the minimum fruit size and weight was obtained at the lowest level of N i.e. N_{50}. These findings are in agreement with those of Buwalda *et al.* (1990), who observed a significant increase in fruit size and weight in kiwifruit cv. Hayward with nitrogen application. Whereas, Vizzotto *et al.* (1999) recorded larger and heavier fruits with increase in N doses upto 300 kg/ha, but found reduction in fruit size and weight with the increase in N application thereafter. The production of heavier berry weight with optimum N dose has also been reported by Dhillon *et al.* (2002). The increase in the fruit size by nitrogenous fertilizer may be attributed to stimulation of growth and photosynthesis and subsequent translocation of assimilates to sustain growth of developing fruits. This gains support from experimental findings of Childers (1966), who reported that addition of N increased the rate of photosynthesis per unit of leaf area as well as the duration of photosynthesis and may increase fruit size and weight. The fruit size and weight showed increasing trend with increase in the K level and the maximum fruit size (length and breadth) and weight was recorded in K_{150}. The results are in conformity with those of Testoni *et al.* (1990), who reported increased fruit size and weight from 102 g to 114 g when K was increased from 0 to 200 kg/ha in kiwifruit. Similarly, P application resulted in increase in fruit size and weight. The maximum fruit size (length and breadth) and weight was recorded under P_{70} treatment. Tagliavini *et al.* (1995) also obtained increase in fruit size with P fertilizer in kiwifruit.

The interactions among N, P and K fertilizers also exhibited significant effect on the fruit size and weight. The application of $N_{100}P_{70}K_{150}$ resulted in the production of fruits of maximum size and weight, which was statistically at par with $N_{150}P_{70}K_{150}$, the second best treatment combination. However, the minimum fruit size and weight was obtained at the lowest levels of N, P and K i.e. $N_{50}P_{35}K_{50}$ treatment. These observations are, more or less, in conformity with the findings of Smith and Miller (1991), Testoni *et al.* (1990) and Ahad *et al.* (1992), who recorded the maximum fruit size and weight with combined application of N, P and K fertilizers at optimum level.

Nitrogen and phosphorus applications failed to produce any significant effect on flesh firmness (Table 11). These results are in conformity with the findings of Scudellari *et al.* (1996) and Costa *et al.* (1997), who reported that N application had no significant effect on flesh firmness in kiwifruit. Similar results were also observed by Muster and Hubner (1994) and Khattari and Shatat (1996) in apple. However, K application had significant effect on flesh firmness. The maximum flesh firmness was recorded in K_{150}. The flesh firmness showed increasing trend with increase in the K level. These findings are in agreement with those of Testoni *et al.* (1990), who recorded the increased flesh firmness with the application of K_2O in kiwifruit.

The flesh firmness was significantly influenced by NxP, NxK, PxK and NxPxK interactions. The application of $N_{100}P_{70}K_{50}$ resulted in the maximum flesh firmness. These results are in accordance with those of Nosal (1995), Mass *et al.* (1998) and Wang *et al.* (2002), who reported that NPK fertilizers significantly increased flesh firmness.

5.3.2 Chemical characteristics of fruit

Application of nitrogenous and phosphatic fertilizers did not show any significant effect on the TSS content in the fruit juice, however, TSS content increased significantly with the increase in dose of K fertilizer and the maximum TSS content was recorded in K_{150}. The present finding in respect of TSS content are in conformity with those of Monastra *et al.* (1997) and Vizzotto *et al.* (1999), who recorded non-significant effect of N at different doses on TSS in kiwifruit. Total, reducing and non-reducing sugars were observed to be maximum in N_{50}, P_{105} and K_{150}, respectively, among the various N, P and K fertilizers levels. Reduction in sugar contents of fruits in present investigation with increasing N levels might be due to the preferential utilization of melabolites in the more luxuriant vegetative growth, developing fruits and utilization of sugars in the synthesis of amino acids and proteins (Boynton *et al.* (1944).

A marked increase in the TSS and sugars with the application of K may probably be due to more synthesis of carbohydrates and other melabolites followed by their translocation to the storage organs. These results are in agreement with the findings of Testoni *et al.* (1990).

The various interactions of N, P and K fertilizers exhibited significant effect on the TSS and sugar contents. The maximum TSS and sugar contents was recorded at higher potassium level in combination with N and P levels. These results are in conformity with those of Nijjar *et al.* (1972) and Sharma *et al* (1979), who also observed significant increase in TSS and sugar content with the application of NPK fertilizers in apricot and peach.

Different N, P and K levels showed significant effect on fruit acidity. An increase in acidity with the increased levels of N was recorded, whereas, increased levels of P and K had inverse effect on the titratable acidity (Table 13). The increase in acidity with N application might be due to the increased synthesis of amino acids, proteins and other metabolities and their consequent translocation to the fruits (Clark *et al.*, 1992). These results are in conformity with those of Nijjar *et al.* (1972), who recorded increase in acidity with N application in apricot and with those of Sharma *et al.* (1979), who reported reduction in the acid content of peach fruit with P and K fertilizer application in the soil.

The ascorbic acid content decreased with increasing levels of N and P (Table 17). The results are in accordance with those of Vizzotto *et al.* (1999), who also reported that ascorbic acid content decreased with increasing levels of N in kiwifruit. However, ascorbic acid content increased with increasing levels of K. Similar results have also been recorded by He *et al.* (2002) in peach.

5.4 LEAF NUTRIENTS

5.4.1 Macro-nutrient content

Soil applications of NPK fertilizers at various levels were observed to have significant influence on leaf nutrient content. Leaf N, Ca and Mg contents increased whereas, leaf P and K contents decreased with the increase in the N doses. Nitrogen being highly mobile (Kirkby, 1970), its efficient translocation under higher level could have added to its enhanced accumulation in the leaves. Smith and Miller (1991) also reported higher N content in kiwifruit leaves with the increase in doses of N in the soil. Nitrogen status of the leaf has great effect in regulating the uptake or distribution of practically all other elements of which most striking reactions are antagonistic effects between N and P or K (Smith, 1962). The reduction in the P and K contents as a result of higher doses of N can thus be attributed to the antagonistic effects of N with P and K. These findings are in conformity with those of Shikhamany *et al.* (1988) in grapes and Rupp and Hubner (1995) in peach, who also observed reduction in leaf P and K contents with the application of N fertilizer in the soil. Increasing levels of applied N were associated with increased contents of Ca and Mg. The higher Ca and Mg contents with increased level of N application suggest the strong synergism between N and Ca or Mg. Such synergism was also reported by Cain (1953) and Shikhamany *et al.* (1988) in apple and grapes, respectively. Increased Ca content in the leaf with increased rate of N application could be due to higher levels of associated Ca ions with nitrogen nutrition, since N was applied as Calcium Ammonium Nitrate in the present investigation.

With regard to phosphorus application, the leaf P was significantly increased with the increase in doses of P application in the soil, whereas, leaf N, K and Mg contents decreased. However, leaf Ca was not affected with the application of P. These results are in accordance with those of Tagliavini *et al.* (1993), who was of the opinion that addition of P to the soil increased leaf P content but depressed leaf N and K contents. A plausible explanation for lower N and K contents in the leaf may be that high level of P might have curtailed the supply of N to the leaves as reported by

Kenworthy and Gilligan (1948). Loupassaki *et al.* (1997) also observed decrease in the K contents in kiwifruit leaves with P fertilizer.

Varying levels of potash irrespective of N and P levels influenced significantly the leaf macro-nutrient contents. The increasing levels of K were associated with increased K content in leaves as compared to lower level. Whereas, leaf N, P, Ca and Mg contents showed decreasing trend with increasing levels of K application in the soil. Similar results were obtained by Shikhamany *et al.* (1988) in Thompson Seedless grapes. The decrease in N content with increase K levels might be due to the fact that these two nutrients have tendency for preferential accumulation in the leaf (Cook and Kishaba, 1956) and NO_3^- ions are negatively charged, while, K^+ ions are positively charged, they have affinity for each other in neutralizing the charges in the tissue. This could be the reason for antagonism between N and K contents. Similarily, increased rate of K application were associated with increased K content in the leaves. It might be attributed to the higher concentration of K^+ ions released into the soil solution from the clay complex (Steward, 1963). Loupassaki *et al.* (1997), also observed increased leaf K content with the highest level of K in most of the cvs. of kiwifruit.

Decrease in Mg and Ca content with increased application of K in the present investigations are in line with the findings of Cain (1953), Shikhamany and Satyanarayana (1972) and Shikhamany *et al.* (1988), who have reported similar antagonistic effect of K on Mg content in grapes.

Interaction effects of varying levels of N, P and K were found significant on the leaf macro-nutrient elements. Though the varying levels of P on the leaf Ca content was non-significant, but its interaction with N and K levels was found to be significant. In general, higher N and Ca contents of the leaves were associated with higher doses of N coupled with lower doses of P and K. The present findings are in agreement with those of Saini and Singh (1975), who also recorded higher leaf N in treatments having higher doses of N and lower doses of P and K. The P content of leaves was found higher with highest level of P along with lowest levels of N and K. Similarly, leaf K was recorded more with medium levels of N and P coupled with highest dose of K and Mg content of the leaves was highest with $N_{150}P_{35}K_{100}$. These results are in conformity with those of Smith and Miller (1991), who reported significant effect on the N and K content in the leaves of kiwifruit vines supplied with NPK mixture (12:10:10), as compared to the control vines. Similar observations were also recorded by Monastra *et al.* (1995) in kiwifruit and Shikhamany *et al.* (1988) in grape vines.

5.4.2 Micro-nutrients

Soil application of different levels of NPK fertilizers exerted a significat effect on leaf micro-nutrient contents. In the present study, the leaf Zn, Fe, Cu and Mn contents increased significantly with the increase in levels of nitrogen. These findings are in line with the observations of Dhillon *et al.* (2002), who obtained higher Zn, Fe and Mn contents in nitrogen treated vines as compared to non-nitrogen fertilized grape vines. Similarly, Testoni *et al.* (1990) also observed that increased levels of nitrogen application significantly increased the leaf micro-nutrient contents in kiwifruit. The synergistic effect of N on leaf Mn content was also observed by Shikhamany *et al.* (1988) in grape vines.

With respect to P application, it was observed that leaf Zn and Mn contents were significantly increased with increased P levels; however, no consistent trend was observed on leaf Fe content. The leaf Cu content showed non-significant effect with the application of P fertilizer. Similarly, the application of K at varying levels resulted in increased Zn content but the leaf Fe showed decreasing trend with increasing K levels,which indicates that K had antagonistic effect on Fe content. The findings are in agreement with those of Shikhamany *et al.* (1988), who also observed antagonistic effect of K on Fe content in petioles of Thompson Seedless grapes. Similar observations were also made by Sharma and Singh (1982), who observed increased Fe, Zn and Cu contents of leaves with K fertilizers in peach. There was no consistent effect on the Mn contents in the leaf with the different levels of K.

Interactions among the various levels of N, P and K were found to exert significant effect on the micro-nutrient concentrations in the leaves. Zinc content of the leaves was observed higher with $N_{150}P_{105}K_{100}$ treatment. The combination of lowest levels of K and higher N, resulted in highest Fe content in the leaves. The Cu and Mn contents were recorded highest with $N_{150}P_{70}K_{150}$ and $N_{150}P_{105}K_{150}$ combinations, respectively. The increased levels of Fe, Zn, Cu and Mn contents in leaves may be attributed to the acidifying effect of N fertilizer (Mengel and Kirkby, 1982), which might have lowered the soil pH and increased the absorption of Fe, Zn and Cu contents.

The variation in the micro-nutrient elements at different levels of N, P and K might be attributed to the cumulative effect of N in acidification of the soil solution in the medium root zone (Mengel and Kirkby, 1982) and the synergistic and antagonistic effects of K on Cu and Fe, respectively, as reported by Shikhamany (1988). The increased Fe and Mn contents in the leaves in present study is in line with the findings of Testoni *et al.* (1990) in kiwifruit. Similarly, Kassem *et al.* (1994) also recorded increased leaf Fe and Mn contents with the application of NPK fertilizers in apple.

5.6 AVAILABLE NUTRIENT CONTENTS OF THE SOIL

In the present study available N in the soil increased with the increasing N, P and K fertilizers. Increase in available N in the soil may be attributed to marked increase in the availability of NH_4^+ ion to the soil bacteria for nitrification and to produce NO_3^- ions, and thus increasing the availability of N in the soil. These results are in conformity with those of Rom and Arrington (1974) and Singh (1992), who also observed an increase in the availability of N in soil following NPK fertilizers application.

The available P content of soil was increased over the initial status (Table 28) with the application of P fertilizer. However, available P content of the soil decreased with increase in levels of N, but increased with increasing levels of P, whereas, no definite trend was observed with the application of increased levels of K. The decrease in soil P with the increase in levels of N may be attributed lowering of soil pH due to higher N fertilizer. Fe and Al oxides become more effective at low pH, thereby increasing the phosphorus fixation in the soil. The present results are in conformity with those of Singh (1982) and Singh (1992), who observed decrease in available P content of soil with increasing levels of N in peach. However, phosphorus application increased the available phosphorus in soil. This could be expected because of the addition of phosphorus to the soil.

Nitrogen as well as potassium application in the soil resulted in a marked increase in available potassium content of the soil (Table 29). This might be due to increase in K^{+} ion concentration in the soil solution. The increase in acidity due to N application might have favoured sublimation of K and other cations (Kanwar, 1979). Singh (1982) reported that increased supply of N and K fertilizers increased the soil K availability. Similar results have been reported by Sharma (1987) and Singh (1992) in peach. However, P application exhibited inconsistent effect on the K content in the soil.

The combined application of N, P and K and their interactions were observed to have a significant effect on the available N, P and K contents in the soil. The available N, P and K contents in the soil increased with the combined application of NPK fertilizers. These results are in conformity with those of Singh (1982), who observed significant increase in available N, P and K contents in the soil of peach orchard following the application of NPK fertilizers.

SUMMARY AND CONCLUSION

Nitrogen as well as potassium applications to the soil resulted in a marked increase in available potassium content of the soil (Table 29). This might be due to increase in K^+ ion concentration in the soil solution. The increase in acidity due to N application might have increased solubilization of K and other cations (Kanwar, 1979). Singh ([illegible]) reported that increased supply of N and K fertilizers increased the soil K availability. Similar results have been reported by Sharma (1987) and Singh (1992) in [illegible]. However, P application exhibited inconsistent effect on the K content in the

The combined application of N, P and K and their interactions were observed to have a significant effect on the available N, P and K contents in the soil. The available N, P and K contents in the soil increased with the combined application of these nutrients. These results are in conformity with those of Singh (1982), who reported significant increase in available N, P and K contents in the soil of peach orchard from the application of NPK fertilizers.

SUMMARY AND CONCLUSION

Chapter-6

SUMMARY AND CONCLUSION

The present investigations on the "Studies on the effect of N, P and K fertilizer levels on growth, yield and quality of kiwifruit cv. Allison" were conducted during 2002-2003. The salient findings of the studies are summarized as under:

1. The maximum vine girth and annual shoot growth was recorded in $N_{150}P_{105}K_{100}$, while, the minimum vine girth was observed in $N_{50}P_{35}K_{50}$ and annual shoot growth in $N_{50}P_{70}K_{100}$.

2. The maximum yield was recorded in $N_{100}P_{70}K_{150}$, while, the minimum yield was found in $N_{50}P_{35}K_{50}$.

3. The maximum yield of A grade fruits was observed in $N_{150}P_{70}K_{150}$ and minimum in $N_{50}P_{70}K_{50}$.

4. The maximum yield of B grade fruits was recorded in $N_{150}P_{105}K_{50}$. The minimum yield of B grade fruits was found in $N_{50}P_{35}K_{150}$.

5. The maximum yield of C grade fruits was recorded in $N_{50}P_{35}K_{150}$ and the minimum in $N_{100}P_{35}K_{150}$.

6. The maximum fruit size and weight was obtained in $N_{100}P_{70}K_{150}$ and minimum fruit length was recorded in $N_{50}P_{35}K_{50}$, fruit breadth in $N_{150}P_{70}K_{50}$ and fruit weight in $N_{50}P_{70}K_{50}$.

7. The maximum flesh firmness was recorded in $N_{100}P_{70}K_{50}$ and minimum in $N_{150}P_{70}K_{50}$.

8. The maximum TSS was recorded in $N_{100}P_{70}K_{50}$, $N_{100}P_{70}K_{100}$, $N_{100}P_{35}K_{150}$, $N_{50}P_{105}K_{100}$ and $N_{50}P_{105}K_{150}$. The minimum TSS was observed in $N_{150}P_{35}K_{50}$.

9. The maximum titratable acidity was recorded in $N_{50}P_{35}K_{50}$ and minimum in $N_{100}P_{105}K_{50}$, $N_{100}P_{105}K_{150}$ and $N_{50}P_{105}K_{150}$.

10. The maximum total and non-reducing sugars were observed in $N_{50}P_{35}K_{150}$. While, the minimum total sugars were observed in $N_{100}P_{105}K_{50}$ and non-reducing sugars in $N_{150}P_{70}K_{100}$.

11. The maximum reducing sugars was recorded in $N_{100}P_{70}K_{100}$ and minimum in $N_{150}P_{35}K_{50}$.

12. The maximum ascorbic acid content was found in $N_{50}P_{70}K_{150}$ and minimum in $N_{150}P_{105}K_{150}$.

13. The maximum leaf N content was recorded in $N_{100}P_{35}K_{50}$. While, the minimum leaf N content was recorded in $N_{50}P_{105}K_{150}$.

14. The maximum leaf P content was observed in $N_{50}P_{105}K_{50}$ and minimum in $N_{150}P_{35}K_{100}$.

15. The maximum leaf K content was recorded in $N_{100}P_{35}K_{150}$. While,the minimum leaf K content was observed in $N_{150}P_{105}K_{50}$.

16. The highest leaf Ca content was recorded in $N_{150}P_{35}K_{50}$. While,the lowest leaf Ca content was found in $N_{50}P_{35}K_{100}$.

17. The maximum leaf Mg content was recorded in $N_{150}P_{35}K_{100}$. While, the minimum leaf Mg content was observed in $N_{50}P_{105}K_{50}$.

18. The maximum leaf Zn content was found in $N_{150}P_{105}K_{100}$ and minimum in $N_{50}P_{35}K_{50}$.

19. The maximum leaf Fe content was observed in $N_{100}P_{70}K_{50}$. While, the minimum leaf Fe content was found in $N_{100}P_{35}K_{100}$.

20. The maximum leaf Cu content was recorded in $N_{150}P_{70}K_{150}$ and minimum in $N_{50}P_{105}K_{100}$.

21. The maximum leaf Mn content was recorded in $N_{150}P_{105}K_{150}$. While,the minimum leaf Mn content was observed in $N_{150}P_{35}K_{50}$ and $N_{50}P_{70}K_{50}$.

22. The maximum available soil N was recorded in $N_{150}P_{105}K_{150}$. While, the minimum available N was observed in $N_{50}P_{70}K_{50}$.

23. The maximum available soil P was observed in $N_{50}P_{105}K_{100}$. While, the minimum available P was recorded in $N_{50}P_{35}K_{50}$.

24. The maximum available soil K was recorded in $N_{150}P_{35}K_{150}$ and minimum in $N_{50}P_{105}K_{50}$.

On the basis of results obtained in the present investigations, it may be concluded that soil application of 100 g N, 70 g P_2O_5 and 150 g K_2O / year age of vine of cv. Allison resulted in the production of higher yield of better size and quality fruits.

REFERENCES

REFERENCES

A.O.A.C. 1980. Official methods of analysis of analytical chemists, 18th Ed. (ed. W. Horowitz). Association of the Official Analystical Chemists, Washington, D.C. p. 1018.

Ahad, S.F.; Nawab, A. and Mukamil, S. 1992. Effect of NPK and fungicidal sprays on fruit quality and yield of apple. *Sarhad J. Agric.* 8(2): 167-174.

Arora, R.L.; Tripathi, S. and Singh, R. 1999. Effect of nitrogen on leaf mineral nutrient status, growth and fruiting in peach. *Indian J. Hort.* 56(4): 286-294.

Badyal, J. 1980. Nutritional studies on plum (*Prunus salicina* Lindl.) cv. Santa Rosa. Ph.D. Thesis, HPKV, Palampur, India.

Ben-Arie, R.; Gross, J. and Sonego, L. 1982. Changes in ripening parameters and pigments of the Chinese gooseberry (kiwi) during ripening and storage. *Scie. Hort.* 18: 65-70.

Bhan, S. 1986. Studies on the repeated application of fertilizer alone or in combiantion with herbicides in plum cv. Santa Rosa. Ph.D. Thesis, HPKV, Palampur, India.

Borghi, T.; Malpezzi, G.; Carnevali, G.; Maltoni, R. and Sansavini, S. 1995. Fertilizer trial on peaches. 21st Convegno Peschicolo, Lugo, Ravenna. 223-232 p.

Bovha, D. 1997. Comparison of conventional with reduced fertilizer application in grapevine. *SAD Revija Za Sadjarstro Vinogradinistvo Vinarstvo.* 8(9): 17-21.

Boynton, D. 1944. Response of young Elberta peach and Montmorency cherry trees to K fertilization in New York. *Proc. Amer. Soc. Hort. Sci.* 44: 31-33.

Bussi, C. and Amiot, M.J. 1998. Effect of nitrogen and potassium fertilization on the growth, yield and pitburn of apricot (cv. Bergeron). *J. Hort. Sci. Biotech.* 73(3): 387-392.

Bussi, C. and Defrance, H. 1986. Fertilizing irrigation in a peach orchard. Results of three years of trials. *Arboriculture Fruitiere.* 33(387): 45-48.

Bussi, C.; Hugnet, J.G. and Defrance, H. 1991. Fertilization scheduling in peach orchards under Trickle irrigation. *J. Hort. Sci.* 66(4): 487-493.

Buwalda, J.G. and Meekings, J.S. 1993. Temporal expression of effects of varying nitrogen supply on canopy growth, photosynthesis and fruit production for *Actinidia deliciosa* vines in the field. *Physiologia plantarum.* 89(1): 48-54.

Buwalda, J.G. and Smith, G.S. 1991. Influence of anions on the potassium status and productivity of kiwifruit (*Actinidia deliciosa*) vines. *Plant and Soil.* 133: 209-218.

Buwalda, J.G.; Wilson, G.J. and Smith, G.S. and Littler, R.A. 1990. The development and effects of nitrogen deficiency in field - grown kiwifruit (*Actinidia deliciosa*) vines. *Plant and Soil.* 129: 173-182.

Cain, J.C. 1953. The absorption and distribution of mineral nutrients in apple trees as affected by nutrient supply. *Proc. Amer. Soc. Hort. Sci.* 62: 53-66.

Chapman, H.D. 1964. Suggesting foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops. *Indian J. Hort.* 21: 97-119.

Chekan, A.S. 1988. The effect of annual and periodic (alternate year) application of macro and micronutrient fertilizers on the physiological state and productivity of apple trees. *Vliyanie Udobrenii Obmen Veschestv Produktivnost Rastenii.* 128-138.

Childers, N.F. 1966. Strawberry nutrition. **In:** Temperate to tropical fruit nutrition, Rugers the State Univ. New Burnswick, New Jersey. pp. 518-548.

Choureitah, A. and Lenz. 1974. Fruit quality characteristics in sour cherries in relation to different N and K levels. *Erwerbrobstbau.* 16(9): 136-138.

Clark, C.J.; Smith, G.S. and Boldingh, H.L. 1992. The effect of nitrogen fertilization on the free amino acid composition of kiwifruit during development and postharvest storage. *Scientia Horticulturae.* 52(1-2): 85-94.

Cook, J.A. and Kishaba, T. 1956. Petiole nitrate analysis as a criterion of nitrogen needs in California vineyards. *Proc. Amer. Soc. Hort. Sci.* 68: 131-140.

Costa, G.; Lain, O.; Vizzoto, G. and Johnson, S. 1997. Effect of nitrogen fertilization on fruiting and vegetative performance, fruit quality and post harvest life of kiwifruit cv. Hayward. *Acta Hortic.* 444: 279-284.

Crespan, G.; Colugnati, G.; Bregant, F.; Tonetti, I.; Gallas, A.; Tagliavini, S.; Kubiskin, C. and Montanari, M. 1999. Foliar applciation to vines. *Vignevini.* 26(5): 47-50.

Cummings, G.C. 1978. Plant and soil effects of fertilizer and time applied to higher bush blue beries. *J. Amer. Soc. Hort. Sci.* 103: 302-305.

Dadlani, S.A.; Singh, B.B. and Kazim, M. 1971. Chinese gooseberry, a new fruit. *Indian Hort.* 16(2): 13.

Dillon, W.S.; Bindra, A.S. and Brar, B.S. 2002. Effect of fertilization on fruit yield, quality and nutrient status of grape cv. Perlette. *Indian J. Hort.* 59(3):270-274.

Dzhalilova, G.A. 1991. Application of mineral fertilizers in a sweet cherry orchard. *Sadovovodstvo i Vinogradarstvo.* 8: 16-17.

FAO, 2002. http://www.faostatdatabase.org/.

Ferguson, A.R. and Eiseman, J.A. 1983. Estimated annual removal of maconutrients in fruits and pruning from kiwifruit orchard. *New Zeal. J. Agr. Res.* 26: 115-117.

Franco, A. 1990. Kiwifruit : producers and markets. *Acta Hortic.* 282: 21-29.

Ganai, M.R.; Talib, A.R. and Handoo, G.M. 1995. Standardization of fertilizer requirement for cherry (*Prunus avium*). *Fertilizer News.* 40: 53-55.

Georgiev, S. 1988. The effect of nitrogen fertilization on the chemical composition of young cherry tree leaves. *Rasteniev dni Nauki.* 25(6): 68-73.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. John Wiley and Sons, Inc., New York. pp.680.

Havelka, B. 1970. Checking the N, P and K nutrition levels in peach trees by the leaf diagnosis. *Acta Universitatis Agricultural, Brno. A.* 18(4): 621-623.

He, Z.J.; Tong, Y.; Zhang, G.W.; Ma, J.; Li, X.P. and Zhang, G.L. 2002. Effect of potash application on the output and quality of Dangshan Suli pear variety in loess area. *J. Fruit Sci.* 19(1): 8-11.

Hipps, N.A.; Ridout, M.S. and Atkinson, D. 1990. Effect of alley sward width, irrigation and nitrogen fertilizer on growth and yield of Cox's Orange Pippin apple trees. *J. Sci. Food Agri.* 53(2): 159-168.

Hipps, N.A.; Val, J.; Montanes, L. and Monge, E. 1997. Effects of nitrogen, phosphorus, water and pre-planting soil sterilization on growth and yield of Queen Cox/M9 apple trees. *Acta Hortic.* 448: 125-131.

Jackson, M.L. 1967. Soil chemical analysis. Asia Publishing House, Bombay, p. 408.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall, India Pvt. Ltd., New Delhi.

Jadczuk, E.; Lipecki, M.; Jokubczyk, H.; Lata, B.;l Sadowski, A. and Whitehead, P. 1998. Influence of K fertilization on growth, yield and leaf mineral concentration in Katja apple trees. Ecological aspects of nutrition and alternatives for herbicides in horticulture. International Seminar, Warszewa Poland, 10-15 June, 1997: 27-28.

Jia, H.; Hirano, K. and Okamoto, G. 1999. Effects of fertilizer levels on tree growth and fruit quality of 'Hakuho' peaches (*Prunus persica*). *J. Japenese Soc. Hort. Sci.* 63(3): 487-493.

Johnson, R.S.; Mitchell, F.G. and Costa, G. 1997. Nitrogen influences kiwifruit storage life. *Acta Hortic.* 444: 285-289.

Kanwar, J.S. 1979. Investigation on pruning and fertilization requirement on peach (*Prunus persica* Batsch.) cv. Flordasun Ph.D. Thesis, Punjab Agricultural University, Ludhiana, India.

Kanwar, J.S. and Nijjar, G.S. 1983. Effect of different pruning and fertilizer treatments on growth, yield and quality of peach (*Prunus persica* Batsch.). cv. *Flordasun. Indian J. Hort.* 40: 48-54.

Kassem, H.A.; Elsabrout, M.S. and Elshazly, S.M. 1994. Soil fertilization study of Anna apple trees grown in calcareous soil. *Alexandria J. Agri. Res.* 39(3): 571-584.

Kenworthy, A.L. and Gilligan, G.M. 1948. Inter - relationship between the nutrient content of soil, leaves and trunk circumference of peach trees. *Proc. Amer. Soc. Hort. Sci.* 51: 209-215.

Kepka, M.; Adowski, A.S.; Kozanecka, T. and Solbisz. 1982. Chemical properties of orchard soil, growth and fruiting of apple trees as affected by different nitrogen and potassium fertilizer levels. **In**: Abstracts of Contibuted Papers. Proc. 21st Int. Hort. Cong., Hemberg., West Germany. p. 1272.

Khattari, S.K. and Shatat, F. 1996. Effect of ammonium sulphate rate, and doses of application on yield and fruit quality of the apple cv. Starkrimson. *Dirasat Agri. Sci.* 23(2): 84-88.

Khayat, R.A. and Dujaili, J.A. 2001. Effect of pruning and nitrogen fertilizer levels and their interaction on quantitative characteristics of two grape cultivars (Halwani and Kamali) (*Vitis vinifera* L.). *Dirasat Agri. Sci.* 28(1): 87-98.

Khokhar, U.U. 1984. The influence of nitrogen, potassium and herbicides on growth, nutrient status, yield and quality of plum. Ph.D. Thesis, HPKV, Palampur, India.

Kirkby, E.A. 1970. Nitrogen nutrition of the plant. The University of Leeds Press, Leeds.

Komamura, K., Suzuki, A.; Fukumoto, M.; Kato, K. and Sato, Y. 2000. Effects of long term nitrogen application on tree growth, yield and fruit qualities in a 'Jonathan' apple orchard. *J. Japenese Soc. Hort. Sci.* 69(5): 617-623.

Kumar, J. 1984. Effect of various systems of orcahrd soil management at different levels of N in Santa Rosa plum. Ph.D. Thesis, HPKV, Palampur, India.

Lalatta, F.; Visai, C. and Failla, O. 1990. Application of leaf analysis on kiwifruit orchards in northern Italy. *Acta Hortic.* 282: 187-192.

Lipecki, J. 1990. The use of growing doses of NPK in different localizations in apple orchard. *Acta Hortic.* 274: 289-296.

Loupassaki, M.H.; Andronlakis, I.I. and Lionakis, S.M. 1997. Effect of P and K fertilizers and of the date of sampling on the concentration of macro and micro elements in the leaf of four kiwi cultivars. *Acta Hortic.* 444: 249-254.

Lysenko, M.K.; Demidenko, R.N. and Khamdamova, N.D. 1974. The effect of mineral nutrition on changes in the chlorophyll and organic carbon content in apple leaves. **In**: Biologicheskie Nauki : Alma Ata, Kazakh, SSR, 6: 146-149.

Lysiak, G.P.; Pacholak, E. and Sass, P. 1994. The influence of different doses of fertilization on storage of apples, cv. Cortland. *Acta Hortic.* 368: 547-551.

Males, P. 1998. Effect of fertilization on yield and nutritional state of grapevine cultivars Emerald Riesling and Rkaciteli. *Agronnomski Glasnik.* 60(1-2): 17-23.

Marangoni, B.; Toselli, M.; Scudellari, D.; Brigati, S.; Neri, F.; Spada, G.L. and Sansavini, S. 1995. Peach fertilization and fruit quality. 21st Convegno Reschicolo, Lugo, Ravenna, 27-28 August 1993. 201-209 pp.

Marsh, K.B.; Stowell, B.M. and Tillman, R.W. 1992. Options for supplying potassium to kiwifruit vines. *Acta Hortic.* 297: 337-343.

Mass, R.V.; Hof, M. and Vander, M.R. 1998. Better result with nitrogen manuring based on leaf content early in the season. *Fruitteelt Den Haag.* 88(44): 18-19.

Meheriuk, M.; Neilsen, G.H. and Hogue, E.J. 1995. Influence of nitrogen fertilization and orchard floor management on yield, leaf nutrition and fruit quality of Fairhaven peach. *Fruit Varieties J.* 49(4): 204-211.

Mengel, K. and Kirkby, E.A. 1982. Principles of plant nutrition. 3rd ed. International Potash Institute A.G. Bern/ Switzerland.

Monastra, F.; Strabbioli, G.; Rapareili, E.; Turci, E.; Cappelloni, M. and Vivanti, V. 1997. Slow releasing fertilizer effects on kiwi fruit orchard. *Acta Hortic.* 444: 273-277.

Monastra, F.; Strabbioli, G.; Turci, E. and Cappelloni, M. 1995. Yield and mineral status of a kiwifruit orchard supplied with slow-release fertilizers. *Acta Hortic.* 383: 475-480.

Muster, G. and Hubner, H. 1994. Nitrogen yield and fruit quality of apples. Results from a longterm fertilizer trial. *Erwerbsobstbau.* 36(2): 44-48.

Nijjar, G.S. 1996. Nutrition of fruit trees. Kalyani Publishers, New Delhi. 311p.

Nijjar, G.S.; Deol, S.S. and Bajwa, M.S. 1972. Effect of N, P and K on vigour, cropping and quality of New Castle apricot. *J. Res.* 9: 261-263.

Noe, N.; Ecoher, T.; Stainer, R.; Porro, D.; Tagliavini, M.; Neilsen, G.H. and Millard, P. 1995. Influence of nitrogen, phosphorus and magnesium fertilization on fruit quality and storability of Golden Delicious apples. *Acta Hortic.* 383: 439-447.

Nosal, K. 1995. Effectiveness of fertilizing the apple cultivars McIntosh, Jonathan and Bancroft with nitrogen and potassium. *Zeszyty Naukowe Akademil Rolniczej im Hugona Kollataja w Krakowla Rozprawy.* 196: 72 pp.

Olsen, S.R.; Cole, C.V.; Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus by extraction with sodium bicarbonate. *USDA Cir.* 939.

Orphanos, P.I. 1992. An NPK experiment with Sultanina grapes. *Technical Bulletin Cyprus Agricultural Research Institute.* 141: 10pp.

Paap, J.; Jakubozyk, H; Lata, B.; Sadowski, A. and Whitehead, P. 1998., Studies on nitrogen supply to Jonathan apple trees in long term experiments. Ecological aspects of nutrition and alternatives for herbicides in horticulture. International seminar, Warszawa, Poland, 10-15 June, 1997.

Pacholak, E. 1990. Fertilizing and irrigating in an intensive apple orchard in relation to cropping of the cultivar 'James Grieve'. *Prace Zakresu Nauk Rolniczych.* 69: 87-100.

Piatkowski, M.S.; Pronka, K. and Olszewski, T. 1990. Effect of fertilization of two apple cultivars with macro and micro elements. *Acta Hortic.* 274: 383-386.

Piper, C.S. 1966. Soil and plant analysis. Hans Publication, Bombay, p. 368.

Ritter, C.M. 1956. Effect of varying rates of nitrogen fertilization on young Elberta peach trees. *Proc. Amer. Soc. Hort. Sci.* 95(3): 338-341.

Rogers, E. 1969. Mineral content of peach trees as affected by nitrogen source and rate. *J. Amer. Soc. Hort. Sci.* 94(4): 352-353.

Rom, R.C. and Arrington, E.H. 1974. Relationship of soil and foliar tests in assaying the nutrient status of peach orchards. **In**: Proceedings of the 95th annual meeting. Arkaneas State Horticultural Society, 1974. Fort Smith, USA (undated): 49-54.

Rupp, D. and Hubner, H. 1995. Influence of nitrogen fertilization on the mineral content of apple leaves. *Erwerbsobstbau.* 37(1): 29-31.

Sadowski, A.; Jadczuc, E.; Neilsen, D.; Fallahi, B.; Neilsen, G. and Peryea, F. 2001. Results of 11-year N-fertilizer trials in a sour cherry orchard. *Acta Hortic.* 2001: 564: 279-284.

Sadowski, A.; Jadczuk, E.; Jurczak, B.; Tagliavini, M.; Neilsen, G.H. and Millard, P. 1995b. Effects of preplanting P fertilization in sour cherry orchards. *Acta Hortic.* 383: 239-246.

Sadowski, A.; Ostrowska, J.; Pacholak, E.; Szwedo, J. and Wrona, D. 1995a. Effects of nitrogen fertilizer application in trials in comemrcial apple orchards. 939-942.

Saenz, J.L.; DeJong, T.M. and Weinbaum, S.A. 1997. Nitrogen stimulated increases in peach yields are assocaited with extended fruit development period and increased fruit sink capacity. *J. Amer. Soc. Hort. Sci.* 122(6): 772-777.

Saini, S.S. and Singh, R.N. 1975. Effect of nitrogen, phosphorus and potassium on the nutritional status of young vines. *Haryana J. Hort. Sci.* 4(1-2): 1-10.

Scudellari, D.; Spada, G.; Tagliavini, M.; Zavallonic, C.; Marangoni, B. and Ponti, I. 1996. Effect of nitrogen and calcium fertilizers on the yield and quality of kiwifruit. *Societa Orticola Italiana.* 501: 203-208.

Sharma, A.K.; Grewal, S.S. and Singh, G. 1979. Effect of N, P and K on vigour, fruit size and fruit quality of Sharbati peach. *Punjab Hort. J.* 19: 49-51.

Sharma, M.M. 1995. Comparative response of some temperate fruits to foliar application of urea. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, India.

Sharma, M.R. and Singh, R. 1982. Yield and chemical composition of peach leaves as influenced by NPK fertilization. *Punjab Hort. J.* 22: 93-98.

Sharma, Y.P. 1987. Response of peach trees to nitrogen and weed management practices. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, India.

Shikhamany, S.D. and Satyanarayana, G. 1972. An approach for predicting the occurrence of interveinal chlorosis in Anab -e-Shahi grape (*Vitis vinifera* L.). *Vitis.* 11: 218-221.

Shikhamany, S.D.; Chelvan, R.C. and Chadha, K.L. 1988. Effect of varying levels of nitrogen and potash on petiole nutrient contents in Thompson seedless grape (*Vitis vinifera* L.). *Indian J. Hort.* 45(3-4): 180-188.

Singh, D. 1992. Effect of pruning intensities under different levels of nitrogen on growth, yield and quality of peach (*Prunus persica* Batsch.) cv. July Elberta. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, H.P., India.

Singh, D. and Singh, R. 2002. Nitrogen nutrition of peach - a review. *Agricultural Reviews.* 23(1): 46-52.

Singh, N.P. 1982. The studies on the nutrition of peach (*Prunus persica* Batsch.) cv. Flordasun in relation to pruning. M.Sc. Thesis, HPKV, Palampur, India.

Smith, C.B. 1962. Mineral analysis of plant tissue. *Plant Physiology.* 13: 81-108.

Smith, G.S. and Miller, S.A. 1991. Osmotic effects on performance and fruit quality of kiwifruit vines. *Acta Hortic.* 297: 331-336.

Soing, P.; Lobit, P. and Ardoin, N. 1998. Nitrogen in peach trees : Is post harvest fertilizer necessary? *Infos-Paris.* 146: 32-35.

Steward, F.C. 1963. Plant Physiology - A treatise. Academic Press, New York, Vol. III: 57-61.

Stoilov, G. and Marinov, P. 1979. Changes in the major element content of apricot leaves during growth. *Gradinarska i Iosorska Nauka.* 16(2): 28-37.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of the available nitrogen in soil. *Curr. Sci.* 25: 259-260.

Sud, G. 1987. Nutritional requirements and storage behaviour of apricot cv. New Castle. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni,Solan, India.

Svagzdys, S. 1990. Use of calcium fertilizers in apple orchards grown on neutral and alkaline soils. *Acta Hortic.* 274: 455-460.

Swati, S.A.; Wazir, F.K. and Asghar, H. 1990. Effect of different levels of NPK on growth, pre-harvest fruit drop, yield and quality of apricot (*Prunus armeniaca*) cv. Trevatt. *Sarhad J. Agri.* 6(6): 571-574.

Szucs, E.; Hampson, C.R.; Anderson, R.L.; Perry, R.L. and Webster, A.D. 1996. Effect of nutrient supply on frost hardiness and fruit set of sour cherry flowers and on yield. *Acta Hortic.* 410: 551-553.

Tagliavini, M.; Hogue, E.J. and Neilsen, G.,H. 1993. Phosphate and peat additions effect growth, P and N nutrition of peach seedlings in virgin and replant peach soil. *Acta Hortic.* 324: 97-106.

Tagliavini, M.; Toselli, M. and Pelliconi, F. 1995. Nutritional status of kiwifruit affects yield and fruit storage. *Acta Hortic.* 383: 227-233.

Tartachinik, I.I. 1997. Effect of high nitrogen fertilizer doses on the frost resistance, growth processes and fruit quality of apple trees. *Sadovodstvo i Vinogradarstvo.* 3: 7-9.

Terra, M.M.; Brasil, S.M.; Pires, E.; Nagai, V. and Bravdo, B.A. 2000. Six years of NPK fertilizer experimentation with grapevine cultivar 'Niagara Rosada', growing in a podzol soil. in Indoiatuba, S.P., Brazil. *Acta Hortic.* 326: 235-239.

Testoni, A.; Granelli, G. and Pagano, A. 1990. Mineral influence on the yield and quality of kiwifruit. *Acta Hortic.* 282: 203-208.

Tewari, J.C.; Divakar, B.L.; Adhikari, K.S. and Negi, R.S. 1992. Effect of nitrogen and potash fertilizers on nutrient composition of leaf and stem girth of peach trees. *Prog. Hort.* 21(3-4): 308-313.

Treglazova, N.V. and Fataliev, A.T. 1994. Effect of combined mineral top dressing on apple storability. *Sadovodstvo i vinogradarstvo.* 4: 11.

Trunov, Y.V. and Shishkarev, E.A. 1998. Fertilizer application in an intensive apple orchard on weak -growing stocks. *Sadovodstvo i Vinogradorstvo.* 3: 7-8.

Velasco, R.A.; Cervantes, E.P.; Enriquez; J.C.; Prados, N.C. and Rodriquez, J.H. 1992. Soil mulching and nitrogen fertilization of apples (*Malus silvestris* Mill.) with rain water from storms. Proceedings of a conference held in Granada, Spain, on 3-8 May, 1992.

Verma, K.S. and Bhandari, A.R. 1996. Effect of NPK and micronutrients on the fruit yield and quality of peach (*Prunus persica* Batsch.). *Scientific Hort. J.* 5: 27-34.

Vitanova, I. 1973. The effect of nitrogen fertilization on the available nitrogen in the soil and total nitrogen content in the leaves of Kyaslendilska Sinya plum. *Gradinarskailozarska Nauka.* 10: 153-158.

Vitanova, I. 2002. Mathematical analysis on optimizing the nitrogen fertilizing of plum trees of Stanley cultivar. *Pochvoznanie Agrokhimiya Ekologiya.* 33(2): 12-13.

Vizzotto, G.; Lain, O. and Costa, G. 1999. Relationship between nitrogen and fruit quality in kiwifruit. *Acta Hortic.* 498: 165-172.

Vorob, V.F. 1996. Effect of doses of mineral fertilizers on the keeping properties and quality of Antonovka Obyknovennaya apples. *Sadovodstvo i Vinogradarstvo.* 4: 11-12.

Walsh, C.S.; Allnutt, F.J.; Miller, A.N. and Thompson, A.H. 1989. Nitrogen level and time of mechanized summer shearing influence long term performance of a high density Redskin peach orcahrd. *J. Amer. Soc. Hort. Sci.* 114(3): 373-377.

Wang, Q.; He, W.H.; Guo, J.N.; Huang, X.A.; Jiao, S.M. and He, Y.H. 2002. Effect of application of potassium fertilizer on production and fruit quality of apple trees. *J. Fruit Sci.* 19(6): 424-426.

Wrona, D.; Sadowski, A.; Ostrowski, J.; Tagliavini, M.; Neilsen, G.H. and Millard, P. 1995. Potassium fertilization trials in commercial apple orchards. *Acta Hortic.* 383: 481-486.

Zegbe, J.A. 1995. Influence of planting season, fertilization and pruning at transplanting on initial development of local peach trees under rainfed conditions. *Revista Filolechfa Mexicana.* 18(2): 91-106.

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Title of Thesis		**Studies on the effect of N, P and K fertilizer levels on growth yield and fruit quality of kiwifruit cv. Allison**
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ABSTRACT

The investigations were conducted on seven-year-old vines of kiwifruit cv. Allison having uniform growth, vigour and size, planted at a spacing of 4 m x 6 m and trained on T-bar system. The vines were given uniform cultural practices during the course of investigation. The experiment was laid out in randomized block design with three levels of each N (50, 100 and 150 g/year age of vine), P (35, 70 and 105 g/ year age of vine) and K (50, 100 and 150 g/ year age of vine) in twenty seven factorial combinations. Each treatment was replicated three times with one vine under each replication. The maximum vine girth and annual shoot growth was recorded in $N_{150}P_{105}K_{150}$, while, the minimum vine girth was observed in $N_{50}P_{35}K_{50}$ and annual shoot growth in $N_{50}P_{35}K_{50}$. The highest total yield and yield of 'A' grade fruits was recorded in $N_{100}P_{70}K_{150}$, while, the lowest yield was found in $N_{50}P_{35}K_{50}$. The maximum yield of C grade fruits was recorded in $N_{50}P_{35}K_{50}$ and the minimum in $N_{150}P_{35}K_{150}$. The vines fertilized with $N_{100}P_{70}$ and K_{150} produced fruits of maximum size and weight, whereas the minimum fruit size and weight was found in $N_{50}P_{35}K_{50}$. The maximum flesh firmness and TSS content was recorded in $N_{100}P_{70}K_{50}$ and minimum firmness in $N_{150}P_{70}K_{50}$ and TSS in $N_{150}P_{35}K_{50}$. The highest total and non-reducing sugars was observed in $N_{50}P_{35}K_{150}$, while, the lowest total sugars was observed in $N_{100}P_{105}K_{50}$ and non-reducing sugars in $N_{150}P_{70}K_{100}$. The maximum ascorbic acid content was found in $N_{50}P_{70}K_{150}$ and minimum in $N_{150}P_{105}K_{150}$. The highest leaf N, P, K, Ca and Mg contents was recorded in $N_{100}P_{35}K_{50}$, $N_{50}P_{105}$, K_{50}, $N_{100}P_{35}K_{150}$, $N_{150}P_{35}K_{50}$ and $N_{150}P_{35}K_{100}$ respectively. Similarly, the maximum leaf Zn, Fe, Cu and Mn contents were recorded in $N_{150}P_{105}K_{100}$, [illegible], [illegible] and [illegible] respectively. The maximum available soil N, P and K was recorded in [illegible], [illegible] and $N_{150}P_{35}K_{150}$, while the minimum was observed in [illegible], [illegible] and [illegible] respectively. On the basis of results obtained in the present investigations, it may be concluded that soil application of 100 g N, 70 g P_2O_5 and 150 g K_2O / year age of vine of cv. Allison resulted in the production of higher yield of better size and quality fruits.

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