EFFECT OF NPK AND FREQUENCY OF CUTTINGS ON YIELD AND QUALITY IN *Amaranthus tricolor* L.

By

DEEPA SUKUMAR

THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF HORTICULTURE
Vellanikkara - Thrissur

1997

DECLARATION

I hereby declare that the thesis entitled **"Effect of NPK and frequency of cuttings on yield and quality in *Amaranthus tricolor* L."** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other university or society.

Deepa Sukumar

Vellanikkara

7-7-1997

DEEPA SUKUMAR

CERTIFICATE

Certified that the thesis entitled "**Effect of NPK and frequency of cuttings on yield and quality in *Amaranthus tricolor* L.**" is a record of research work done independently by **Miss. Deepa Sukumar**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Dr.S.Rajan
Chairman
Advisory Committee
Professor and Head i/c
Department of Olericulture
College of Horticulture
Vellanikkara

Vellanikkara
7-7-1997

CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss. Deepa Sukumar, a candidate for the degree of **Master of Science in Horticulture,** with major in **Olericulture,** agree that the thesis entitled "**Effect of NPK and frequency of cuttings on yield and quality in *Amaranthus tricolor* L.**" may be submitted by Miss. Deepa Sukumar, in partial fulfilment of the requirement, for the degree.

Dr.S.Rajan
Chairman
Professor and Head i/c (Olericulture)
College of Horticulture
Vellanikkara

Dr.V.K.G.Unnithan
Associate Professor (Statistics)
College of Horticulture
Vellanikkara

Smt.Meagle Joseph
Assistant Professor (Olericulture)
College of Horticulture
Vellanikkara

Dr.A.Augustine
Assistant Professor (Biochemistry)
College of Horticulture
Vellanikkara

EXTERNAL EXAMINER
S. NATARAJAN
8.8.97

ACKNOWLEDGEMENT

*I express my sincere gratitude to **Dr.S.Rajan**, Professor and Head i/c, Department of Olericulture and Chairman of my advisory committee for his meticulous and gracious guidance, constant and inspiring encouragement, constructive criticisms and forbearance all through the research work, all of which contributed the most to the completion of the study and for the critical scrutiny of the manuscript. I admit that it has been a rare privilege for me to have worked under his guidance.*

*No words can truly represent my esteemed gratitude to **Dr.A.Augustine**, Assistant Professor, Biochemistry for his timely help, valuable guidance and whole-hearted co-operation towards the satisfactory fulfilment of this endevour.*

*I wish to place on record my profound gratitude and indebtedness to **Dr.V.K.G.Unnithan**, Associate Professor, Agricultural Statistics for his valuable advice and help rendered in the statistical analysis of the data and subsequent interpretation.*

*I extend my sincere thanks to **Smt.Meagle Joseph**, Assistant Professor, Department of Olericulture for the valuable help and criticisms given by her during the course of my investigation and preparation of thesis.*

My profound gratitude is due to Dr.A.I.Jose, Dean, College of Horticulture for his valuable guidance and help rendered during the preparation of thesis.

I am very much indebted to each and every member of the Department of Olericulture for rendering all possible help.

It is with immense pleasure that I thank all my friends each of who has contributed in some way or other towards the completion of this work. In this context, I would like to specially thank Ambili Anand, Seeja, Lincy Davis, Sreekala, Reni, Anu, Savitha, Ancy, Sheena, Bindu, Veena, Anitha, Mini, Nimmy, Joicy and Ayisha who have contributed in no small measure to the success of this venture.

I further express my sincere thanks to Sri. Joy for his commendable care and labour put in, to do the typing of this thesis elegantly.

With gratitude and affection, I recall the boundless affection and warm blessings given to me by my beloved parents and sister to undertake this endeavour successfully.

Above all, I place my heartfelt gratitude and fervent indebtedness to Satguru Sreemath Saraswathy Amma, for her bountiful blessings. I submit this small venture at the lotus feet of Her Divine Grace.

Deepa Sukumar

DEEPA SUKUMAR

dedicated to

Satguru Sreemath Saraswathy Amma

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Green leafy vegetables represent an excellent component of the habitual diet in tropical countries making it richer in minerals, vitamins and proteins. Amaranthus is the most common leafy vegetable grown during summer and rainy seasons in India. It occupies a unique place with regard to easiness in culture, high suitability for both home gardening and commercial cultivation, faster growth rate, freedom from pests and diseases, low production costs and high productivity per unit area. The exact estimation of the extent of its cultivation is not available but it finds a place in every kitchen garden in Kerala. Commercial growing of amaranth has been taken up in small pockets in Kerala and in Tamil Nadu. The warm humid tropical climate is so congenial for amaranth cultivation. Fresh leaf yield as high as 30 t ha^{-1} in four weeks from direct sowing can be realised from this crop. This may be the highest yield/unit of land and per unit of time that can be obtained from any such leafy vegetable.

Amaranth is one of the cheapest leafy vegetables available in the market eventhough it is so rich in minerals, vitamins and essential micronutrients and is often described as 'Poorman's vegetable'. Every 100 g of edible portion of *Amaranthus tricolor* contain 4 g protein, 2.7 g minerals, 397 mg calcium, 3.49 mg iron, 341 mg potassium, 9,200 I.U. vitamin A, 99 mg vitamin C, 247 mg magnesium, 83 mg phosphorus, 230 mg sodium, 0.03 mg thiamine, 88 mg chlorine, 1.2 mg niacine and 0.3 mg riboflavin (National Institute of Nutrition, 1991). The nutritional deficiency condition that needs to be given top priority for remedial action in India today is xerophthalmia. The WHO today estimates that half a million children go blind every year from xerophthalmia and several million more exhibit other symptoms of vitamin A deficiency. The malnutrition due to vitamin A deficiency can be alleviated by including adequate quantities of amaranth in our diet.

Amaranth seeds also contain essential aminoacids such as lysine, methionine, and tryptophan and are rich in protein. It is to be noted that approximately 192 million children under five years of age suffer from acute or chronic protein-energy malnutrition and anaemia. Mixing amaranth seeds with the cereal based diet will augment the protein quality and quantity in a vegetarian diet and thereby reducing the protein-energy malnutrition in developing countries. The puffing quality of the seeds is a good characteristic rendering a pale white flour that can be easily mixed well with most of the culinary preparations without altering flavour (Thomas and Krishnamurthy, 1988).

Despite the high degree of nutritive value, the main constraint to their nutritional exploitation is the presence of some anti-nutritional factors like oxalates and nitrates in the leaves (Cheeke and Bronson, 1980; Gupta and Wagle, 1988). The oxalate levels in foods are of concern because free oxalates bind essential dietary divalent minerals, primarily calcium and make them nutritionally unavailable. Besides, the calcium oxalates thus formed may accumulate resulting in oxalurea or kidney stones. The present levels of oxalates and nitrates however do not pose a nutritional problem under normal conditions of amaranth consumption.

Non-season bound nature and amenability for succession or relay cropping techniques make the greens available throughout the year. Under Kerala conditions harvesting by repeated cutting is preferred to a single harvest by uprooting as it provides several crops from one planting, hence a more efficient resource utilization. It is well suited for home gardens and assures seed availability after flowering.

In spite of great utility of amaranthus little attention is paid to evolve suitable package of practices for remunerative cultivation of the crop. Vegetable harvest coupled with seed production is a viable proposition to maximise net returns. The foliage of the crop is cut arbitrarily by the growers several times and sold. Thereafter the crop is left for seed production or abandoned. The economic cultivation of the crop for seed production has also to be taken into account. The number of cuttings need to be standardised as both the under and over cutting may lead to poor seed production in terms of quality, nutrient uptake and net returns. The number of cuttings may also be affected by the input management, particularly of nitrogen, phosphorus and potassium. The present study was therefore undertaken with the following objectives:

1. To find out the optimum number of vegetable cuttings that can be taken so as to get maximum net returns.
2. To study the effect of different levels of nitrogen, phosphorus and potassium on the amaranth seed crop.
3. To assess the quality of the greens as influenced by the vegetable harvest and NPK application.
4. To assess the quality of seeds as influenced by the vegetable harvest and NPK application.

Review of Literature

2. REVIEW OF LITERATURE

Formulation of economic levels of fertilizers required for maximisation of crop profits is a vital step in any crop management programme. Another major decisive factor of profit maximisation in the case of green leafy vegetables is the number of vegetable cuttings taken. The available literature relevant to the present investigation have been reviewed here under:

2.1 Growth attributes and vegetable yield

Van Eijnatten (1970) reported that during the rainy season in tropical areas the production of green leaves from some amaranthus species could reach 12-17 t ha^{-1}. Kamalanathan *et al.* (1973) in their studies on evaluation of vegetable amaranthus types reported that the type CO-1 was superior recording an yield of 19,000 kg ha^{-1}. Mugerwa and Bwabye (1974) investigated the productivity of a number of tropical grasses and legumes and commented that as reported by Van Eijnatten (1970) none of these yielded as much dry matter in a period of two months as amaranthus (9000 kg ha^{-1}). They suggested that because of its rapid growth, it would be possible to take two crops of amaranthus in a growing season. They also pointed out that in two rainy seasons in Uganda, four crops and yields exceeding 40 t of dry matter per year were possible.

Mohideen and Shanmugasubramanian (1974) found that green yield of amaranthus had a significant positive correlation with number of leaves, weight of leaves, leaf length, leaf breadth, length of stem, weight of stem and diameter of stem. Rajagopal *et al.* (1977) compared the performance of CO-1 and CO-2 amaranthus and found that CO-2 amaranthus was superior. CO-2 amaranthus recorded an yield of 10,780 kg ha^{-1} at 25th day and 16,200 kg ha^{-1} at 30th day after sowing as compared to 6578 kg and 12,789 kg ha^{-1} respectively in CO-1 amaranthus.

Purushothaman (1978) observed that application of nitrogen increased yield of *Amaranthus viridis*. Ramachandra (1978) studied the effect of different levels of N and P on growth and yield of *Amaranthus gangeticus*. Both nutrients applied at the highest rates increased plant height, dry weight, leaf area index and yields.

Hauplti and Jain (1980) observed a wide variation in flowering time, height, seed yield, harvest index and seed size in *Amaranthus cruentus*. According to them late maturity, tallness and yield were correlated positively with each other but negatively with harvest index.

Mohideen and Muthukrishnan (1980) conducted studies on correlation, multiple regression and path analysis related to yields of vegetable amaranth harvested by pulling out the whole plant at 25th day after sowing. The genotypic and phenotypic correlation coefficients computed at the 25th day of harvest revealed that weight of leaves and stem were more closely associated with yield of greens. The path coefficient analysis conclusively revealed that weight of leaves, weight of stem, height, stem diameter and breadth of leaf alone attributed their maximum direct and indirect positive effects on yield of greens. Sidhu and Arora (1980) reported the green yield of *Amaranthus dubius* var. CO-1 to be 7-8 t ha^{-1}.

Sulekha (1980) opined that 25 day old seedlings when transplanted gave better growth. Such plants showed early initiation of flowering and thus limiting the number of possible harvests when yield and yield attributes were considered the 15 and 20 days old seedlings performed better. The horticultural potential of 20 vegetable amaranth entries was evaluated by Campbell and Abbott (1982). Mean fresh yields (leaves and stems) ranged from 4.9 to 16.5 t ha^{-1}. Yields of *Amaranthus cruentus* (averaging 10 t ha^{-1}) appeared to be less affected by the early cool wet conditions of the Experiment-I than were yields of *A. dubius* (6 t ha^{-1}) and *A. tricolor* (1-3 t ha^{-1}). Under the excellent growth conditions of Experiment-II, *A. dubius* yielded best (22 t ha^{-1}) followed by *A. cruentus* (18 t ha^{-1}). Yields of *A. tricolor* entries ranged from 4 to 14 t ha^{-1}. Yield was negatively correlated with leaf/stem ratio indicating that the better yielding entries tended towards stemminess. Entries with the highest leaf stem ratio were found with *A. tricolor*.

Vijayakumar *et al.* (1982) conducted studies on growth and development of certain types of amaranth namely, *A. tristis, A. tricolor, A. dubius* and *A. blitum*. They observed that the plant height was significantly associated with the yield of greens (stem and leaves) at all stages of growth.

Keskar *et al.* (1983) studied the effect of nitrogen on yield of chaulai, *Amaranthus blitum*. Nitrogen was applied at 20-50 kg ha^{-1}. The highest average yield (12.17 t ha^{-1}) was obtained from plants which received 50 kg N ha^{-1}. The average yield was 5.72 t ha^{-1} in control (no N). A trial on *Amaranthus tristis* L. with N at 20-60 kg ha^{-1}, showed that the maximum plant height and optimum leaf : stem ratio resulting in the highest green leaf yield was obtained with the highest nitrogen rate applied in a split dose i.e., one half as a basal dressing and other half as a top dressing after 8 weeks from sowing (Singh *et al.*, 1985).

Hilman and Abidin (1987) reported that the plant growth and yield of four amaranthus cultivars increased with increase in the rate of nitrogen application. The same result was again demonstrated by Subhan (1989) by conducting a field trial on *Amaranthus tricolor* L. with four levels of nitrogen (0, 30, 70 and 110 kg ha^{-1}) and found that the plant height, leaf area and fresh weight increased with increasing nitrogen application. The highest yields were obtained with a split application of 110 kg ha^{-1}. Devadas *et al.* (1989) reported that frequency of harvests, days to 50 per cent bolting, length and width of fifth leaf and plant height on bolting day had high genotypic correlation with yield. Frequency of harvests was highly correlated with days to 50 per cent bolting.

Panda *et al.* (1991) conducted a field experiment on *Amaranthus tricolor* L. with nitrogen (as urea) applied at 0, 20, 40 and 60 kg ha^{-1} and P_2O_5 (as single superphosphate) and K_2O (as muriate of potash) applied at 0 and 20 kg ha^{-1}. They obtained the highest fresh yield with 60 kg N + 20 kg P_2O_5 + 20 kg K_2O/ha. According to Makus (1992), phosphorus is the most critical nutrient in an unimproved mineral soil. He also opined that supplemental P_2O_5 increased leaf number per plant and percentage of non-edible stem tissue in vegetable amaranth (*Amaranthus tricolor* L.). Varalakshmi and Reddy (1994) reported that green yield of vegetable amaranthus showed highly significant positive correlation with plant height, leaf length, leaf weight and stem weight.

2.2 Growth attributes and seed yield

Hauplti and Jain (1977) in an evaluation of genetic variation in amaranth collections reported that seed yield was negatively correlated with stem growth in two weedy species while it was positively correlated with yield in domesticated types. Rajagopal *et al.* (1977) reported that seed yield/plant in two promising lines CO-2 (*Amaranthus gangeticus*) and CO-1 (*A. dubius*) as 48.4 g and 10.4 g respectively. In a two year field trial conducted by Pareek and Gupta (1981) nitrogen was applied to fenugreek at 0, 30 and 60 kg ha^{-1} and P_2O_5 at 0, 20, 40 and 60 kg ha^{-1}. The highest seed yield and seed weight were obtained from plants receiving N:P at 30:60 kg ha^{-1}.

An experiment on turnip (*Brassica rapa* L.) with four levels of N (0, 40, 80 and 120 kg ha^{-1}) amd four levels of P_2O_5 (0, 30, 60 and 90 kg ha^{-1}) revealed that N and P_2O_5 favourably increased the plant growth and yield (Ahmed and Tanki, 1988). Plant height, number of branches/plant, number of siliqua/plant, number of seeds/siliqua, siliqua length, seed and stalk yield increased linearly upto 120 kg N ha^{-1} and 90 kg P ha^{-1}. The highest seed yields were obtained with the application of 120 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1} respectively. The response of plants to nitrogen was however much more as compared to phosphorus. Seed yield was positively correlated with growth and yield contributing traits. Optimum doses of nitrogen and phosphorus were 157 kg ha^{-1} and 104 kg ha^{-1} respectively.

According to Reyes *et al.* (1988) *Amaranthus hypochondriacus* L. responds positively upto 300 kg N and 150,000 plants/ha with a tendency to increase yield with a greater number of plants/ha. Kumar *et al.* (1994) conducted an experiment on radish seed crop with four levels of nitrogen (0, 50, 100 and 150 kg ha^{-1}) and three levels of potassium (0, 40 and 80 kg ha^{-1}). The experimental results indicated that application of nitrogen and potassium @ 150 kg ha^{-1} and 40 kg ha^{-1} respectively was the most effective combination which resulted in the production of the highest seed yield.

2.3 Influence of vegetable cuttings

According to Enyi (1965) and Grubben (1976), cuttings significantly delayed bolting in amaranths. In a study to find out the clipping response of two species of amaranthus, Mohideen and Rajagopal (1974) reported that the cultivar 'Arakeerai' (*Amaranthus tricolor* L. var. *tristis*) responded favourably for cutting registering an yield of 11,736 kg ha^{-1} as compared to 'Sirukeerai' (*Amaranthus blitum* L.) with an yield of 8680 kg ha^{-1}. Salini (1975) investigated the effects of varying levels of clipping the leaves and shoots of fenugreek and found that the yield was not affected upto two cuttings. Three clippings gave the highest green leaves followed by two and one clipping. Based on two years trial she recommended that one cutting may be taken 50 days after sowing and crop then left for grains. In the case of three clippings, the time left for shoot emergence and flowering was found shorter resulting in low yields.

Sinha *et al.* (1985) opined that application of 50 kg N/ha was found to be the most economical and one cutting of green leaves gave the highest net return in the case of palak (*Beta vulgaris* L. var. *bengalensis*). According to Olufolagi and Tayo (1989) pruning of amaranthus is superior to uprooting with respect to total numbers of leaves and branches developed, total fresh weight yield and the dry weight of various plant parts. They suggested that planting the indeterminate, late flowering varieties at the start of the rains and continuously cutting back is a more profitable method of harvesting than uprooting at the optimum commercial stage. Baboo and Sharma (1995) evaluated the effect of nitrogen, phosphorus and cutting management on yield, net returns and uptake of nutrients in fenugreek on a sandy loam with low organic carbon and available N and medium in available phosphorus and potassium. The results inferred that the yield and net return increased with increase in the nitrogen dose. The highest dose of 80 kg P_2O_5/ha applied gave markedly higher seed yield over lower rates of phosphorus. They also concluded that crop left for seed after one cut at 20 days gave the highest yield, yield attributes and net returns.

2.4 Seasonal influence

Mohideen and Muthukrishnan (1981) in their study on 75 types of amaranthus (*Amaranthus gangeticus* L.) in two seasons reported that the yield of greens progressively increased from 20-35 days while the leaf/stem ratio (by weight) showed a decrease. The increase in growth was well marked from 20th-25th day as compared to other stages of growth. The authors suggested that the leaf/stem ratio of around one is considered optimum for a well balanced green matter production. The study also led to fix the optimum stage of harvest as 25th day after sowing for selection of vegetable amaranth types. They also concluded that the summer season is suitable for maximum expression of characters as compared to the monsoon season. According to Hackett and Carolance (1982), the favourable temperature range for amaranthus is 26-30°C and the upper limit of day and night temperature are 45°C and 30°C respectively.

In two season trials on *Amaranthus tricolor* L. with nitrogen at 50-200 kg ha^{-1} and phosphorus at 50-100 kg ha^{-1}, Ramachandra and Thimmaraju (1983) observed that the yields were highest (11.6 t ha^{-1}) in the summer crop receiving the highest nitrogen rate as compared to the autumn crop which yielded 10.6 t ha^{-1} at the same nitrogen rate. The response to phosphorus was found to be less marked.

2.5 Qualitative characters

2.5.1 Oxalate content

The presence of considerable quantities of oxalic acid and nitrate in numerous leafy vegetables especially in amaranth led to the belief that the recommendation of large quantity of leafy vegetables in human nutrition is harmful (Sadik, 1971). One of the biological functions generally attributed to oxalic acid is that it locks the cations thus causing a physiological deficiency of these nutrients. The absolute amounts of these minerals are therefore of little value unless considered in relation to the oxalic acid content. Foods with high oxalic acid are also reported to cause various disorders and even death (Singh *et al.*, 1971; james, 1968; Jeghers and Murphy, 1945). Singh and Sharma (1968) demonstrated that some of the leaves like *Kulfa*, although very rich in calcium and protein are not suitable for health owing to high content of oxalic acid. A concentration as high as 30 per cent of oxalic acid in leaves of bathua (*Chenepodium album*) is reported in literature (Singh and Sur, 1962).

Sreevastava and Krishnan (1959) analysed tissues of several vegetable plants for total and soluble oxalates. They pointed out that the young leaves contained a larger proportion of water soluble oxalates compared to the mature and old leaves. They observed a total oxalate content of 12.78 per cent in the leaves and 12.67 per cent in the stalk of *Amaranthus gangeticus* on dry weight basis. The total oxalate content of spinach leaf was 14.12 per cent while that of the stalk was 5.35 per cent.

A survey conducted by Singh (1973) revealed that the oxalate consumption is fairly high in India. He estimated a total oxalate content of 5.8 per cent in amaranthus spp. Calcium value of foods has often been expressed on the basis of calcium/oxalic acid ratio (Iengar and Rao, 1952; Ackerman and Gebauer, 1957). Iengar and Rao (1952) suggested that the foods having this ratio below 0.3 were not good sources of calcium and those below 0.2 should be considered as very poor sources. According to the criterion laid down by these authors, the leaves of amaranth were not a good source of calcium and those of *Chenopodium* were very poor sources. Similarly, the edible portions of all the leafy vegetables evaluated by Singh (1973) were also very poor sources of calcium.

Ndyanab (1974) observed that forages which contained high levels of calcium and nitrogen also contained high levels of total oxalates but low soluble oxalate levels. Animals fed with diet including *Amaranthus hybridus* did not show any clinical signs of ill health. This is in agreement with the findings reported by Talapatra *et al.* (1948) and Watts (1959) that the high protein content of amaranthus offsets the toxic effects of the oxalate.

Mugerwa and Bwabye (1974) have estimated an oxalic acid content of 6.7 per cent in the whole plant of *A. hybridus* sub sp. *incurvatus*, 7.1 per cent in the leaf and 5.8 per cent in the stem. In an experiment conducted by Mugerwa and Stafford (1976) the mean oxalate levels in both *Amaranthus hybridus* sub sp.

incurvatus and *A. hybridus* sub sp. *hybridus* were found to be higher than those of the Ugandan gramineous forages which were reported to be rich in oxalate by Ndyanab (1974). They further observed that the greater percentage of the oxalate was in insoluble form. Total oxalate content of *A. hybridus* sub sp. *incurvatus* was 4.89 per cent out of which 2 per cent was water soluble. *A. hybridus* sub sp. *hybridus* showed a total oxalate content of 5.25 per cent of which 1.13 per cent was water soluble. *Amaranthus* species are known to contain high levels of both calcium and protein (Mugerwa and Bwabye, 1974). Mugerwa and Stafford (1976) opined that most of the oxalates occurred as calcium and protein bound oxalates.

Deutsch (1977) studied the genetic variation of nutritional value in several amaranth species. According to him genotype x environmental interactions appeared large for oxalate, calcium and protein contents. He also opined that healthy adults need not be concerned about the presence of these compounds as the leafy greens make up only a fraction of the daily food intake. One would need a daily intake of more than 100 g of fresh green to raise the nitrate and oxalate levels. He indicated that oxalates become more of a problem when plants are grown under stress. Studies on the consumption of leafy vegetables revealed a daily intake of 5 g/caput in Latin America, 11 g in central and 21 g in Africa (Grubben, 1976). This intake is definitely non-consequential as compared to 100 g required for causing nutritional defects due to the higher nitrate and oxalate levels.

Experiments conducted by Pingle and Ramasastri (1976) on adult humans showed that calcium in amaranthus leaves is poorly absorbed and that when the leaves were given along with milk, they rendered the milk - calcium less available for absorption. The probable reason attributed by the authors for the poor absorption of calcium from amaranthus leaves was the high oxalate content.

Marderosian *et al.* (1980) analysed different species and accessions of amaranthus for oxalate content over two growing seasons. Mean oxalate levels were about 0.75% (FW) for leaves and 0.06% for stems. They also concluded that the presence of these substances does not significantly detract from the excellent nutritional quality of amaranth greens.

Hill and Rawate (1982) recorded in *A. retroflexus* 5.36 per cent oxalic acid in the leaves and 2.66 per cent in the stems on dry weight basis. Devadas (1982) reported a variation from 0.94 to 1.29 per cent for oxalate in 25 genotypes of vegetable amaranthus. Mallika (1987) reported a variation from 3.6 to 5.1 per cent for oxalate in eight amaranthus species. Meena *et al.* (1987) estimated the soluble oxalate content in amaranth (*Amaranthus tricolor* L.) as 52 per cent and Ca : oxalate ratio as 0.6.

Vityakon and Standal (1989) estimated the total oxalate content in vegetable amaranth (*A. tricolor* L.) and a high amount of 91 g kg^{-1} of dry matter was recorded. They isolated potassium and magnesium oxalate which were soluble in boiling water and an associated insoluble residue which was predominantly calcium oxalate. Thamburaj *et al.* (1994) reported variation in the oxalate content from 0.82 to 1.92 per cent in 41 types of amaranthus. They observed that red colour types had higher oxalate content compared to green colour types.

The relationship between nutrient supply and oxalate accumulation need much attention. The amount and source applied govern the effects of fertilizers on oxalate accumulation in vegetables. According to Grutz (1956) cations promote oxalic acid formation while anions inhibit it. High P_2O_5 application obstructs oxalic acid formation so that the promoting effect of Ca cannot take effect. Oxalic acid formation was also reduced by N applied as ammonium nitrate. The general disturbances in the nutrient supply, result in increased levels of oxalic acid in spinach.

Ehrendorfer (1961) recorded the lowest oxalic acid content in spinach when high rates of N were applied with low rates of K. Oxalic acid content decreased with increasing P contents in leaves. Increasing the leaf P content by fertilizer application had a greater effect on oxalic acid content in the spring than in the autumn.

Eheart and Marsey (1962) conducted an experiment to determine the effect of factors such as variety, soil moisture, light intensity, rate of growth and time of harvest on the oxalate content of spinach. The dry matter content and yield were affected by these factors but as these factors had very little effect on the oxalate content. It was concluded that the high oxalate content of spinach is an inherent physiological characteristic of the plant.

Effect of nitrogen supply on growth, yield, ascorbic acid and oxalic acid content of spinach was studied by Verma *et al.* (1969). Nitrogen was applied at 80, 120, 160 or 200 kg ha^{-1}. Increasing levels of N increased the yield and dry matter content of the tops and decreased the oxalic acid content. Schmidt *et al.* (1971) made assessments of the total and soluble oxalate content of leaves of *Amaranthus cruentus, Basella alba, Brassica oleracea* var. *acephala* and *Ipomoea aquaticus* on soils of medium and high fertility. The average total oxalate contents were: *Basella* 10.62 per cent, *Amaranthus* 8.86 per cent, *Ipomoea* 2.81 per cent and *Brassica* 1.5 per cent. In *Amaranthus* and *Basella* total leaf oxalate content was 25 per cent higher on the more fertile soil but in *Brassica* and *Ipomoea* the content was not affected.

According to Singh (1974) nitrogen in the form of calcium ammonium nitrate did not affect oxalate concentration at the level of 15 kg/acre, but the application of larger amount of fertilizer reduced it progressively. Urea nitrogen also depressed both total and soluble oxalate in the leaf whereas in the stem there was an increase in the production of total oxalate. According to him the form in which the nitrogen is applied influences the oxalate synthesis differently and this influence may be specific to individual plant species.

In a trial on *A. tristis* L. with N at 0-60 kg ha^{-1}, Singh *et al.* (1985) reported that the highest leaf oxalic acid content was estimated with the highest nitrogen rate applied in a split dose i.e., one half as a basal dressing and other half as a top dressing after eight weeks from sowing.

Sarah (1986) reported a variation from 4.43 to 10.4 per cent in kharif and 6.17 to 12.63 per cent in summer for oxalate content in 19 genotypes of amaranths. She also reported that N application reduced the oxalate content. Very high values of oxalate were recorded in summer in all the genotypes.

2.5.2 Nitrate content

Nitrate accumulation in plants is a natural phenomenon resulting from uptake of the nitrate ion in excess of its reduction and result in subsequent accumulation. Accumulation of nitrate is dependent on and related to the genetic make up of the plant, the nitrate supplying power of the soil, and the environmental conditions under which the plant is grown. In addition nitrate concentrations differ in plant parts and with age of the plant.

Nitrate is a natural constituent in plants, and concentration within plants vary with a number of environmental and genetic factors. Plant parts eaten and the amount of nitrate available in the soil appear to be major factors determining whether or not a vegetable will be high in nitrate. Any N fertilizer added as nitrate or capable of being oxidised to nitrate by soil microorganisms and applied in generous quantities to a crop will lead to nitrate accumulation.

Minotti and Stankey (1973) observed a straight forward relationship between the nitrate concentration of outer leaves of head lettuce and the amounts of fertilizer - N applied within a given planting date and N source. However, environmental effects were so pronounced as to completely mask in some cases the effects of fertilizer rates. A summer crop to which no fertilizer was applied contained as much or more nitrate when mature than the spring crop receiving 112 kg N/ha. Similarly, summer lettuce receiving 112 kg N/ha as $NaNO_3$ had higher nitrate concentrations than spring lettuce receiving 224 kg N/ha; summer lettuce receiving 56 kg N/ha as $(NH_4)_2SO_4$ accumulated more nitrate than the spring crop fertilized at four times that rate.

Nitrate concentrations of plant tissues can be expected to bear some relationship to the availability of nitrate in the root zone and in many cases to the amount of fertilizer N applied. Environmental variables may exert a marked effect on nitrate accumulation but they are difficult if not possible to manipulate under production conditions and are equal from one crop growing situation to another, only by rare coincidence (Maynard *et al.*, 1976). In an experiment conducted by Maynard *et al.* (1976), climatic factors acted in such a way as to decrease nitrate with decreasing non-nitrate fraction, much of which consists of useful protein and amino-N. In situations where changes in nitrate were mediated by changes in applied nitrogen, it was observed that increments of fertilizer simultaneously increase non-nitrate N, and this parallel effect extends beyond the critical concentration ranges.

According to Maynard *et al.* (1976) it is not possible to make a general statement about the effect of temperature on nitrate accumulation because the processes of absorption, translocation and assimilation are all affected by other factors such as light, moisture and nitrogen availability. Maynard *et al.* (1976) reported that nitrate accumulation is not appreciably affected by temperature. According to Marderosian *et al.* (1980) mean nitrate levels were 0.08% (FW) for leaves and 0.06 per cent for stems of different amaranthus species. Devadas (1982) reported a variation from 0.55 to 0.94 per cent for nitrate in 25 genotypes of vegetable amaranthus.

The relationship between nutrient supply and nitrate accumulation has been well documented (Commoner, 1970). The amount and source applied and the time and the method of application govern the effects of nitrogen fertilizers on nitrate accumulation in vegetables. The usual effect is that increasing the level of nitrogen nutrition increases the nitrate concentration in vegetables (Barker and Maynard, 1971; Peek *et al.*, 1971; Schmidt *et al.* 1971; Trevino and Murray, 1975).

Barker *et al.* (1971) showed that urea, ammonium nitrate and potassium nitrate side dressed to a spinach crop increased the nitrate concentration but that urea gave the least increase and potassium nitrate the greatest. Schmidt (1971) recorded an average leaf nitrate content of 0.67 per cent in *Amaranthus cruentus*. According to him leaves grown on high fertility soil had an average of 125 per cent more nitrate than those from medium fertility.

Nitrate accumulates with plant age when soil nitrate is uniformly high throughout the growing season. Aworh *et al.* (1979) found that nitrate concentrations increased with age from seed in spinach fertilzed with 340 kg N/ha, whereas it declined with age in unfertilized spinach.

Sarah (1986) reported that nitrate accumulation increased with increasing levels of N in amaranth. Variations due to seasons were not found to be very conclusive in her study. Custic *et al* (1994) reported that increased nitrogen fertilization led to an increased nitrate content is littuce without significantly increasing the yield, although all the nitrate values were still below the maximum limit prescribed by the FAO standards and most European countries.

2.6 Seed characteristics

Kwack and Kang (1985) found that seed germination of *Amaranthus hypochondriacus* was the best in the dark and in red light whereas white and far-red light inhibited it. The differences caused by different light treatments were more marked at 20°C than 30°C but were gradullay obscured by the depressing effects of increasing seed age (upto 3 years) on germination. According to Bartolini and Hampton (1989), physiological maturity of seeds of *Amaranthus cruentus* was reached around 38 days after peak flowering (DAPF) when seed moisture content was 45 per cent. Maximum seed viability (98%) was reached at 30 DAPF and maximum germination at 38 DAPF. However actual germination at this time was only 25 per cent, the rest being dormant. Dormancy was maintained until 65 DAPF.

2.7 Cost of cultivation

The large scale cultivation of any crop depends mainly on the economics of the crop i.e., its cost of cultivation and cost/benefit ratio. The cost of cultivation of amaranthus have been worked out from the Palappur village by Nehru and Thampi (1987). The study was conducted in a village adopted under lab-to-land programme in 1986-87 by the College of Agriculture, Vellayani under the financial assistance of the ICAR. Cost of cultivation of amaranth was studied in comparison with four other vegetables viz. bittergourd, snakegourd, cowpea and bhindi. The results revealed that amaranth cultivation is the most profitable while considering the net profit/unit time. This is followed by bittergourd, snakegourd, cowpea and bhindi. On the other hand, considering profit/season, bittergourd, snakegourd, amaranthus, cowpea and bhindi are the profitable ones in the descending order of the profit.

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken in the Vegetable Research Farm of the Department of Olericulture, College of Horticulture, Vellanikkara, Thrissur. The location is situated at an altitude of 22.25 metres at 10° 32" N latitude and 76° 16" E longitude, with a typical humid tropical climate. The soil type is a well deep, well drained sandy loam with pH of 5.1. The detailed chemical characteristics of the soil before cropping are given in Appendix-I. The experiment was conducted in two seasons viz. from October, 1995 to February, 1996 and February, 1996 to June, 1996. The meteorological observations for the period of study are presented in Appendix-II. The details of the materials and methods used in the study are mentioned below:

3.1 MATERIALS

3.1.1 Crop variety

The amaranth (*Amaranthus tricolor* L.) variety Arun evolved by the Kerala Agricultural University was utilised for the present study.

3.2 METHODS

3.2.1 Experimental design and layout

The experiment was laid out in $(3^3 + 1)3$ partially confounded factorial design with two replications. The higher order interactions NP^2K and NP^2K^2 were partially confounded in replication I and II respectively.

The details of the layout are furnished below:

1. Total number of treatments	84
2. Number of replications	2
3. Number of plots	180
4. Number of blocks	6
5. Spacing	30 x 15 cm
6. Total number of plants/plot	35
7. Gross plot size	2.43 m^2
8. Net plot size	1.575 m^2
9. Total experimental area	400.95 m^2

3.2.2 Treatments

Treatments consisted of the factorial combination of three levels of nitrogen, phosphorus and potassium and three cuttings plus three cuttings without fertilizers.

3.2.3 Levels of nitrogen

1. n_1 50 kg N ha^{-1}
2. n_2 100 kg N ha^{-1}
3. n_3 150 kg N ha^{-1}

3.2.4 Levels of phosphorus

1. p_1 50 kg P_2O_5 ha^{-1}
2. p_2 75 kg P_2O_5 ha^{-1}
3. p_3 100 kg P_2O_5 ha^{-1}

3.2.5 Levels of potassium

1. k_1 50 kg K_2O ha^{-1}
2. k_2 75 kg K_2O ha^{-1}
3. k_3 100 kg K_2O ha^{-1}

3.2.6 Cuttings

1. C_0 - no cutting was taken and the crop was left for seed production alone
2. C_1 - One cutting at 30 days after planting
3. C_2 - C_1 + a second cutting at 20 days after the first cutting

The detailed allotment of treatments and layout are given in Fig.1.

3.3 Field operations

The cultivation practices were carried out as per Package of Practices Recommendation 1993 of the Kerala Agricultural University. The area was divided into blocks and each block was divided into 30 plots. Within each plot five shallow trenches of width 20-30 cm were made 3 cm apart. Well rotten FYM was mixed with soil in the trenches @ 7.88 kg/plot.

3.3.1 Application of fertilizers

Phosphorus and potassium were applied along with half dose of nitrogen as basal application. The straight fertilizers used to supply NPK were urea, super phosphate and muriate of potash respectively.

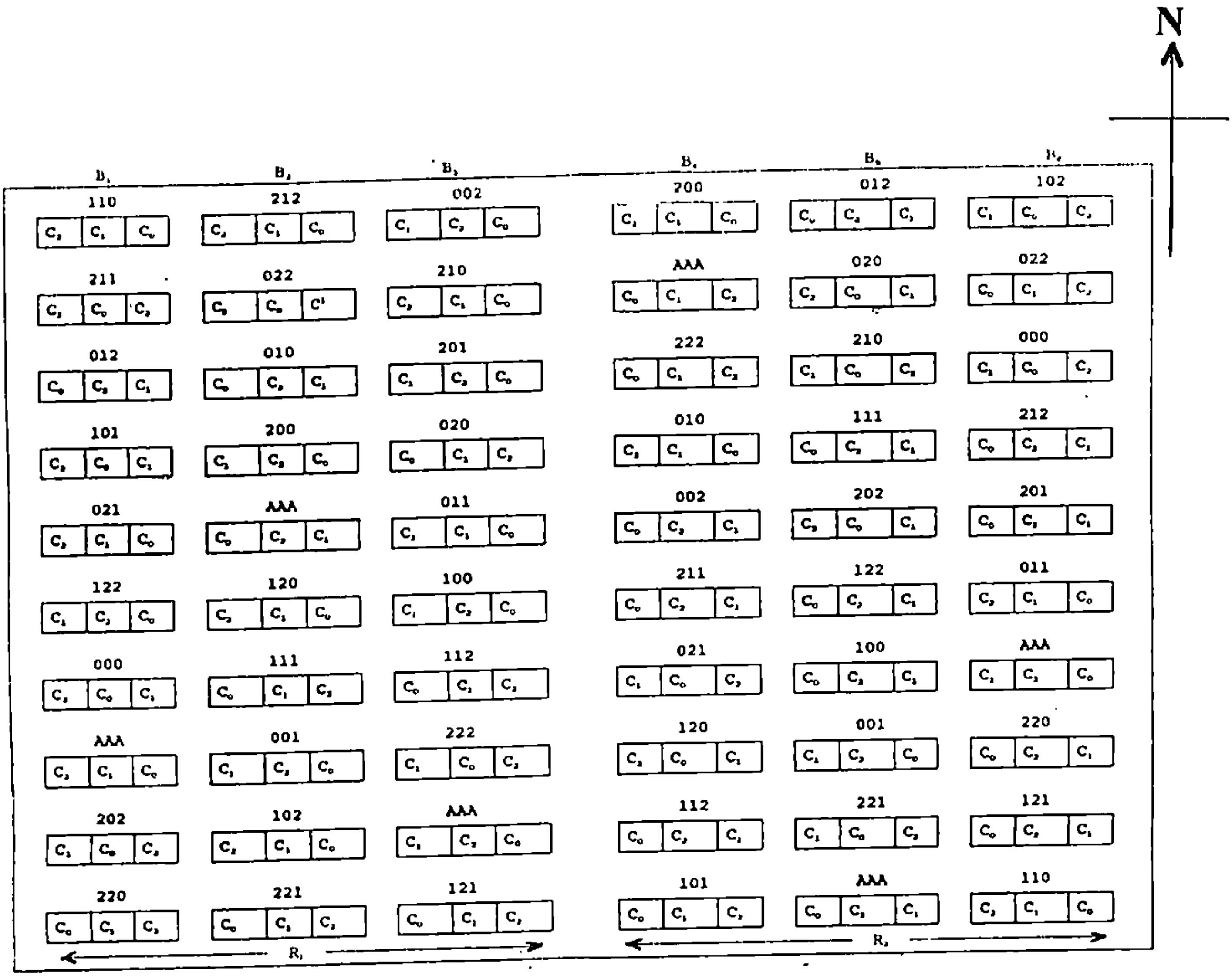

Fig.1. Layout plan $(3^3+1)3$ partially confounded factorial design confounding NP^2K in Rep.I and NP^2K^2 in Rep.II

The topdressing using remaining half of the nitrogen dose was done after 30 days of planting. Besides 1% urea was sprayed after 7 days of each cutting.

3.3.2 Transplanting

30-35 days old seedlings were transplanted in the shallow trenches at a distance of 15 cm.

3.3.3 Weeding

The plots were handweeded frequently to keep them free of weeds.

3.3.4 Plant protection

Need based plant protection measures were taken.

3.3.5 Harvest

After taking the stipulated number of cuttings the crop was left for seed production and seeds were harvested at maturity.

3.4 Observations

3.4.1 Growth components

Height of plant

This observation was taken on five plants selected randomly in each plot after leaving the border lines on four sides. This observation was taken at vegetable harvests and seed harvest.

3.4.2 Yield components

(i) Green yield/plot

Weight of greens from the five observational plants harvested together was recorded and this weight was added to the weight of greens from the rest of 30 plants in the net plot to get total green yield/plot. From this yield/ha was worked out.

(ii) Weight of seeds/plot

Weight of seeds from the five observational plants harvested together was recorded and this weight was added to the weight of seeds from the rest of 30 plants in the net plot to get total seed yield/plot. From this yield/ha was worked out.

3.4.3 Quality of seeds

(i) 100 seed weight

Determination of 100 seed weight was done as per the International Rules for Seed Testing (ISTA, 1985).

(ii) Germination percentage

A total number of 100 seeds selected at random from each treatment were placed in sterilized sand medium and allowed to germinate under ambient conditions. Sufficient moisture was maintained in the germination trays. Daily emergence of seedlings was recorded. The final count was taken at fifteenth day after the first count. The mean number of normal seedlings produced to the total number of seeds sown was expressed as germination percentage.

(iii) Vigour index of seedlings

Vigour index was computed adopting following formula suggested by Abdul-Baki and Anderson (1970).

Vigour index = Germination percentage x Mean length of root and shoot in cm

3.4.4 Chemical analysis

(i) Nitrate and oxalate content

Plant samples were collected from the fields, rinsed in tap water and dried to a constant weight at a temperature of 60-70°C. The dried plant materials were ground to pass through 0.5 mm mesh sieve. Oxalate content of the dried plant sample was assayed by colorimetric method and the nitrate content by distillation technique suggested by Marderosian *et al.* (1980).

3.4.5 Soil analysis

The soil samples collected from the experimental area were analysed for pH and NPK content. Soil pH was measured in 1:2.5 soil water suspension using Elico pH meter (Jackson, 1973). Available nitrogen content of the soil was determined by alkaline potassium permanganate method (Subbaiah and Asija, 1956). The available phosphorus was estimated by Ascorbic acid blue colour method (Watnabe and Olsen, 1965) and the available potassium was determined flame photometrically in the neutral normal ammonium acetate extract of the soil (Jackson, 1973).

3.5 Statistical analysis

The data relating to each character were analysed by applying the analysis of variance technique as given by Panse and Sukhatme (1978) for confounded factorial experiment.

3.6 Economics of cultivation

The yield data were transformed into monetary values based on current market price of amaranthus. Cost of inputs was separately worked out for each treatment. The income after deducting the cost was found out. The benefit cost ratio for each treatment was then worked out.

Plate 1. Field view of the first crop

Plate 2. Field view of the second crop

Results

4. RESULTS

The present investigation to study the effects of different levels of nitrogen, phosphorus and potassium on amaranth seed crop was undertaken to find out the optimum number of vegetable harvests that can be taken for maximum net returns and to assess the quality of the greens and seeds as influenced by the vegetable harvest. The experimental findings are presented below.

4.1 Plant height

4.1.1 Height of plants with no vegetable harvest

4.1.1.1 Main effects of NPK

The data on the main effects are presented in Table 1 and the analysis of variance in Appendix III.

In both the crops, the plant height increased significantly with the increase in nitrogen level. The N_3 level of nitrogen recorded the highest plant height of 47.01 cm, 88.11 cm and 96.43 cm at 30 DAP, 50 DAP and seed harvest stage respectively for the first crop. For the second crop it was 62.98 cm, 108.02 cm and 111.19 cm respectively at 30 DAP, 50 DAP and seed harvest stage. The N_3 level was significantly superior to N_2 level of nitrogen at 30 DAP, 50 DAP and seed harvest stage (39.45 cm, 72.95 cm and 83.18 cm respectively) for the first crop. In the second crop the values were 48.26 cm, 91.89 cm and 96.33 cm at 30 DAP, 50 DAP and seed harvest stage respectively. The N_2 level of nitrogen was significantly superior to N_1 level of nitrogen. These values were 32.7 cm, 58.97 cm and 70.51 cm respectively at 30 DAP, 50 DAP and seed harvest stage for the first crop. In the second crop the plant height was 39.28 cm, 74.79 cm and 79.82 cm at 30 DAP, 50 DAP and seed harvest stage respectively. All the three nitrogen levels were significantly superior to the control which recorded a plant height of 15.1 cm, 31.9 cm and 35 cm respectively at 30 DAP, 50 DAP and seed harvest stage for the first crop. In the second crop the control values were 17.12 cm, 38.65 cm and 39.62 cm at 30 DAP, 50 DAP and seed harvest stage respectively.

The three levels of phosphorus (P_1, P_2 and P_3) recorded higher plant height than the control for both crops. The highest plant height was recorded by P_3 level for the first crop (41.08 cm, 76.18 cm and 85.61 cm at 30 DAP, 50 DAP and seed harvest stage respectively) and for the second crop (52.37 cm, 95.07 cm and 99.05 cm respectively). The P_3 level was significantly superior to P_2 level which recorded plant height of 39.56 cm, 73.5 cm and 83.23 cm at 30 DAP, 50 DAP and seed harvest stage respectively for the first crop. In the second crop the corresponding values were 50.48 cm, 91.86 cm and 95.77 cm respectively. The effect of P_2 level was followed by P_1 level which recorded a plant height of 38.52 cm, 70.36 cm and 81.28 cm at 30 DAP, 50 DAP and seed harvest stage respectively for first crop. In the second crop it was 47.67 cm, 87.78 cm and 92.52 cm respectively at 30 DAP, 50 DAP and seed harvest stage.

The potassium levels also recorded higher plant height than the control. The highest plant height was recorded by K_3 level in the first crop (41.26 cm, 75.2 cm and 85.22 cm at 30 DAP, 50 DAP and seed harvest stage respectively) and in the second crop (52.68 cm, 93.93 cm and 98 cm respectively). This was followed by K_2 which recorded plant height of 39.86 cm, 73.3cm and 83.39 cm at 30 DAP, 50 DAP and seed harvest stage respectively for first crop. The same trend was followed

Table 1. Effect of NPK on the height of plants with no vegetable harvest

	Plant height (cm)					
	First crop			Second crop		
	30 days after planting	50 days after planting	Seed harvest stage	30 days after planting	50 days after planting	Seed harvest stage
Levels of N (kg ha^{-1})						
50	32.70	58.97	70.51	39.28	74.79	79.82
100	39.45	72.95	83.18	48.26	91.89	96.33
150	47.01	88.11	96.43	62.98	108.02	111.19
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2427	0.2389	0.4084	0.4111	0.3835	0.4394
CD(0.05)	0.7042	0.6934	1.1851	1.1929	1.1128	1.2752
Level of P_2O_5 (kg ha^{-1})						
50	38.52	70.36	81.28	47.67	87.78	92.52
75	39.56	73.50	83.23	50.48	91.86	95.77
100	41.08	76.18	85.61	52.37	95.07	99.05
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2427	0.2389	0.4084	0.4111	0.3835	0.4394
CD(0.05)	0.7042	0.6934	1.1851	1.1929	1.1128	1.2752
Levels of K_2O (kg ha^{-1})						
50	38.04	71.50	81.50	47.94	89.22	93.61
75	39.86	73.30	83.39	49.89	91.56	95.74
100	41.26	75.2	85.22	52.68	93.93	98.00
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2427	0.2389	0.4084	0.4111	0.3835	0.4394
CD(0.05)	0.7042	0.6934	1.1851	1.1929	1.1128	1.2752

with second crop (49.89 cm, 91.56 cm and 95.74 cm respectively at 30 DAP, 50 DAP and seed harvest stage). The K_2 level was superior to K_1 level which recorded a plant height of 38.04 cm, 71.5 cm and 81.5 cm at 30 DAP, 50 DAP and seed harvest stage respectively. The corresponding values for second crop were 47.94 cm, 89.22 cm and 93.61 cm respectively.

4.1.1.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops (Table 2a). The N_3P_3 combination recorded the highest plant height of 48.93 cm, 91.8 cm and 98.63 cm at 30 DAP, 50 DAP and seed harvest stage in the first crop. For the second crop the corresponding values were 66.33 cm, 111.45 cm and 114.68 cm respectively. The N_1P_1 combination gave the minimum plant height at 30 DAP, 50 DAP and seed harvest stage for the first crop (31.68 cm, 56.82 cm and 68.6 cm respectively) and for the second crop (37.83 cm, 70.32 cm and 76.8 cm respectively).

For both the crops, nitrogen and potassium interactions were significant (Table 2b). The highest plant height was recorded by N_3K_3 (48.7 cm, 90.22 cm and 98.58 cm at 30 DAP, 50 DAP and seed harvest stage respectively) for the first crop. In the second crop the corresponding values were 67.72 cm, 110.65 cm and 113.42 cm respectively. The lowest plant height was recorded by N_1K_1 (31.37 cm, 57.38 cm and 68.97 cm at 30 DAP, 50 DAP and seed harvest stage respectively) for first crop and for second crop the corresponding values were 38.13 cm, 72.45 cm and 77.6 cm respectively.

Table 2a. Effect of N x P interaction on the height of plants (cm) with no vegetable harvest

Levels of N (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	31.68	32.83	33.60	32.70	56.82	58.45	61.65	58.97	68.60	70.20	72.72	70.51
100	38.15	39.48	40.72	39.45	70.42	73.35	75.08	92.95	81.10	82.97	85.48	83.18
150	45.73	46.37	48.93	47.01	83.83	88.70	91.80	88.11	94.13	96.52	98.63	96.43
Mean	38.52	39.56	41.08		70.36	73.50	76.18		81.28	83.23	85.61	
SEm±	0.4205				0.4139				0.7074			
CD(0.05)	1.2201				1.201				2.052			
Second crop												
50	37.83	39.52	40.48	39.28	70.32	75.03	79.03	74.79	76.80	79.63	83.03	79.82
100	46.2	48.28	50.28	48.26	88.50	92.47	94.72	91.89	92.75	96.80	99.43	96.33
150	58.98	63.63	66.33	62.98	104.53	108.08	111.45	108.02	108.02	110.88	114.68	111.19
Mean	47.67	50.48	52.37		87.78	91.86	95.07		96.52	95.77	99.05	
SEm±	0.7120				0.6644				0.7611			
CD(0.05)	2.0662				1.9277				2.2087			

Table 2b. Effect of N x K interaction on the height of plants (cm) with no vegetable harvest

Levels of N (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	31.37	32.68	34.07	32.70	57.38	58.93	60.60	58.97	68.97	70.47	72.08	70.51
100	37.72	39.62	41.02	39.45	71.10	72.88	74.87	72.95	81.32	83.23	85.00	83.18
150	45.05	47.28	48.70	47.01	86.02	88.10	90.22	88.11	94.22	96.48	98.58	96.43
Mean	38.04	39.86	41.26		71.50	73.30	75.20		81.50	83.39	85.22	
SEm±	0.4205				0.4139				0.7074			
CD(0.05)	1.2201				1.202				2.052			
Second crop												
50	38.13	39.10	40.60	39.28	72.45	74.95	76.98	74.79	77.60	79.72	82.15	79.82
100	46.53	48.50	49.73	48.26	89.72	91.80	94.17	91.89	94.20	96.35	98.43	96.33
150	59.17	62.07	67.72	62.98	105.50	109.92	110.65	108.02	109.02	111.15	113.42	111.19
Mean	47.94	49.89	52.68		89.22	91.56	93.93		93.61	95.74	98.00	
SEm±	0.7120				0.6644				0.7611			
CD(0.05)	2.0662				1.9277				2.2087			

Table 2c. Effect of P x K interaction on the height of plants (cm) with no vegetable harvest

Levels of P_2O_5 (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	38.12	38.20	39.25	38.52	68.67	70.23	72.17	70.36	79.60	81.38	82.85	81.28
75	37.37	40.37	40.95	39.56	71.50	73.53	75.47	73.50	81.57	83.28	84.83	83.23
100	38.65	41.02	43.58	41.08	74.33	76.15	78.05	76.18	83.33	85.52	87.98	85.61
Mean	38.04	39.86	41.26		71.50	73.30	75.20		81.50	83.39	85.22	
SEm±	0.4205				0.4139				0.7074			
CD(0.05)	1.2201				1.201				2.052			
Second crop												
50	46.80	47.62	48.60	47.67	85.63	87.63	90.08	87.78	90.42	92.58	94.57	92.52
75	47.53	50.10	53.80	50.48	89.25	92.00	94.33	91.86	93.28	95.78	98.25	95.77
100	49.50	51.95	55.65	52.37	92.78	95.03	97.38	95.07	97.12	98.85	101.18	99.05
Mean	47.94	49.89	52.68		89.22	91.56	93.93		93.61	95.74	98.00	
SEm±	0.7120				0.6644				0.7611			
CD(0.05)	2.0662				1.9277				2.2087			

Phosphorus and potassium interactions were also found to be significant (Table 2c). The highest plant height was recorded by P_3K_3 for first crop (43.58 cm, 78.05 cm and 87.98 cm at 30 DAP, 50 DAP and seed harvest stage respectively) and for second crop (55.65 cm, 97.38 cm and 101.18 cm respectively at 30 DAP, 50 DAP and seed harvest stage). The lowest plant height was recorded by P_1K_1. These values were 38.12 cm, 68.67 cm and 79.6 cm respectively at 30 DAP, 50 DAP and seed harvest stage for first crop and 46.8 cm, 85.63 cm and 90.42 cm respectively for second crop.

4.1.2 Height of plants with one vegetable harvest

4.1.2.1 Main effects of NPK

The data on the main effects are presented in Table 3 and the analysis of variance in Appendix IV.

At all stages of harvests in both the crops, the plant height increased significantly with the increase in nitrogen level. At first harvest the N_3 level of nitrogen recorded the highest plant height of 47.66 cm, 49.93 cm and 68.13 cm at 30 DAP, 50 DAP and seed harvest stage respectively for the first crop while it was 59.84 cm, 63.55 cm and 102.57 cm respectively at 30 DAP, 50 DAP and seed harvest stage for the second crop. The N_3 level was highly significant and superior to N_2 level of nitrogen (39.74 cm, 41.96 cm and 54.57 cm respectively) for the first crop. In the case of second crop the values were 47.79 cm, 51.49 cm and 88.69 cm at 30 DAP, 50 DAP and seed harvest stage respectively. The N_2 level of nitrogen was highly significant and superior to N_1 level. The values for N_1 level were 31.82 cm, 30.86 cm and 41.55 cm at 30 DAP, 50 DAP and seed harvest stage respectively for the first crop. In the second crop these values were 38.42 cm, 40.94 cm and 76.01 cm respectively at 30 DAP, 50 DAP and seed harvest stage. All the three levels of nitrogen were highly significant and superior to the control which recorded plant height of 16.02 cm, 15.3 cm, and 20.28 cm at 30 DAP (first harvest), 50 DAP and seed harvest stage respectively for the first crop. In the second crop the values were 19.1 cm, 24.4 cm and 35.37 cm at 30 DAP, 50 DAP and at seed harvest stage respectively.

The three levels of phosphorus (P_1, P_2 and P_3) recorded higher plant height than the control at different harvest stages for both the crops. The highest plant height was recorded by P_3 level for the first crop (40.6 cm, 42.79 cm and 57.2 cm at 30 DAP, 50 DAP and at seed harvest stage respectively) and for the second crop (50.97 cm, 54.19 cm and 91.54 cm respectively). The P_3 level was significantly superior to P_2 level which recorded a plant height of 48.64 cm, 51.96 cm and 89.01 cm at 30 DAP, 50 DAP and at seed harvest stage for the second crop while it was 39.91 cm, 40.88 cm and 54.6 cm respectively for the first crop. The effect of P_2 level was followed by P_1 level which recorded a plant height of 38.71 cm, 39.07 cm and 52.44 cm at 30 DAP, 50 DAP and at seed harvest stage for the first crop. In the second crop the corresponding values were 46.44 cm, 49.82 cm and 86.73 cm respectively.

At all stages of harvests, the three levels of potassium recorded higher plant height than the control. The highest plant height was recorded by K_3 level in the first crop (40.74 cm, 42.27 cm and 56.55 cm at 30 DAP, 50 DAP, and seed harvest stage respectively) and in the second crop (50.04 cm, 53.64 cm and 90.94 cm respectively). This was followed by K_2 which recorded a plant height of 39.76 cm, 40.85 cm and 54.73 cm at 30 DAP, 50 DAP and seed harvest stage respectively for

Table 3. Effect of NPK on the height of plants with one vegetable harvest

	Plant height (cm)					
	First crop			Second crop		
	30 DAP (I harvest)	50 DAP	Seed harvest	30 DAP (I harvest)	50 DAP	Seed harvest
Levels of N (kg ha^{-1})						
50	31.82	30.86	41.55	38.42	40.94	76.01
100	39.74	41.96	54.57	47.79	51.49	88.69
150	47.66	49.93	68.13	59.84	63.55	102.57
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2419	0.2408	0.4157	0.3728	0.3458	0.4089
CD(0.05)	0.7018	0.6987	1.2063	1.0819	1.0035	1.1866
Levels of P_2O_5 (kg ha^{-1})						
50	38.71	39.07	52.44	46.44	49.82	86.73
75	39.91	40.88	54.60	48.64	51.96	89.01
100	40.60	42.79	57.20	50.97	54.19	91.54
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2419	0.2408	0.4157	0.3728	0.3458	0.4089
CD(0.05)	0.7018	0.6987	1.2063	1.0819	1.0035	1.1866
Levels of K_2O (kg ha^{-1})						
50	38.72	39.63	52.97	47.35	50.41	87.23
75	39.76	40.85	54.73	48.66	51.93	89.10
100	40.74	42.27	56.55	50.04	53.64	90.94
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2419	0.2408	0.4157	0.3728	0.3458	0.4089
CD(0.05)	0.7018	0.6987	1.2063	1.0819	1.0035	1.1866

the first crop. The same trend was followed in the second crop (48.66 cm, 51.93 cm and 89.1 cm respectively at 30 DAP, 50 DAP and seed harvest stage). The K_2 level was superior to K_1 level which recorded the values of 38.72 cm, 39.63 cm and 52.97 cm at 30 DAP, 50 DAP and at seed harvest stage respectively for first crop. The corresponding values for the second crop were 47.35 cm, 50.41 cm and 87.23 cm respectively.

4.1.2.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant at all the harvest stages for both the crops (Table 4a). The N_3P_3 combination recorded the highest plant height of 48.75 cm, 51.28 cm and 71.25 cm at 30 DAP (first harvest) 50 DAP and at seed harvest stage respectively for the first crop. For the second crop the corresponding values were 63.4 cm, 66.27 cm and 105.22 cm respectively. The N_1P_1 combination gave the minimum plant height of 31.33 cm, 29.02 cm and 39.57 cm respectively at 30 DAP, 50 DAP and seed harvest stages for first crop while in the second crop the corresponding values were 37.17 cm, 39.55 cm and 73.23 cm respectively.

The nitrogen and potassium interactions were significant for both crops, at all harvest stages (Table 4b). The highest plant height was recorded by N_3K_3 (48.83 cm, 51.12 cm and 70.08 cm at 30 DAP, 50 DAP and seed harvest stage respectively for first crop). In the second crop the corresponding values were 61.6 cm, 65.37 cm and 104.65 cm respectively. The lowest plant height was recorded by N_1K_1 (31.1 cm, 29.4 cm and 39.92 cm at 30 DAP, 50 DAP and seed harvest stage respectively for first crop and 37.27 cm, 39.65 cm and 79.93 cm respectively for the second crop).

Table 4a. Effect of N x P interaction on the height of plants (cm) with one vegetable harvest

Levels of N (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	31.33	32.05	32.07	31.82	29.02	30.62	32.95	30.86	39.57	41.40	43.68	41.55
100	37.78	40.47	40.98	39.74	39.50	42.22	44.15	41.96	52.38	54.65	56.67	54.57
150	47.02	47.20	48.75	47.66	48.70	49.82	51.28	49.93	65.38	67.75	71.25	68.13
Mean	38.71	39.91	40.60		39.07	40.88	42.79		52.44	54.60	57.20	
SEm±	0.4190				0.4174				0.7201			
CD(0.05)	1.216				1.2111				2.0897			
Second crop												
50	37.17	38.47	39.62	38.42	39.55	40.73	42.53	40.94	73.23	75.93	78.87	76.01
100	45.55	47.95	49.88	47.79	49.00	51.68	53.78	51.49	86.95	88.60	90.53	88.69
150	56.62	59.50	63.40	59.84	60.92	63.47	66.27	63.55	100.00	102.48	105.22	102.57
Mean	46.44	48.64	50.97		49.82	51.96	54.19		86.73	89.01	91.54	
SEm±	0.6458				0.5989				0.7082			
CD(0.05)	1.8739				1.7382				2.0552			

Table 4b. Effect of N x K interaction on the height of plants (cm) with one vegetable harvest

Levels of N (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	31.10	31.82	32.53	31.82	29.40	30.93	32.25	30.86	39.92	41.52	43.22	41.55
100	38.77	39.62	40.85	39.74	40.57	41.85	43.45	41.96	52.72	54.63	56.35	54.57
150	46.28	47.85	48.83	47.66	48.92	49.77	51.12	49.93	66.27	68.03	70.08	68.13
Mean	38.72	39.76	40.74		39.63	40.85	42.27		52.97	54.73	56.55	
SEm±	0.4190				0.4174				0.7201			
CD(0.05)	1.216				1.2111				2.0897			
Second crop												
50	37.27	38.53	39.45	38.42	39.65	40.80	42.37	40.94	79.93	76.13	77.97	76.01
100	46.55	47.77	49.07	47.79	49.82	51.47	53.18	51.49	87.13	88.75	90.20	88.69
150	58.23	59.68	61.60	59.84	61.77	63.52	65.37	63.55	100.63	102.42	104.65	102.57
Mean	47.35	48.66	50.04		50.41	51.93	53.64		87.23	89.10	90.94	
SEm±	0.6458				0.5989				0.7082			
CD(0.05)	1.8739				1.7382				2.0552			

Table 4c. Effect of P x K interaction on the height of plants (cm) with one vegetable harvest

Levels of P_2O_5 (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	37.96	38.83	39.33	38.71	38.02	39.00	40.20	39.07	50.85	52.85	53.90	52.44
75	38.68	39.95	41.08	39.91	39.30	40.90	42.45	40.88	52.77	54.57	56.47	54.60
100	39.50	40.50	41.80	40.60	41.57	42.65	44.17	42.79	55.28	57.03	59.28	57.20
Mean	38.72	39.76	40.74		39.63	40.85	42.27		52.97	54.73	56.55	
SEm±	0.4190				0.4174				0.7201			
CD(0.05)	1.216				1.2111				2.0897			
Second crop												
50	45.60	46.28	47.45	46.44	48.52	49.73	51.27	49.82	84.93	86.75	88.50	86.73
75	47.05	48.77	50.10	48.64	50.45	51.87	53.57	51.96	87.05	89.05	90.92	89.01
100	49.40	50.93	52.57	50.97	52.27	54.17	56.13	54.19	89.72	91.50	93.40	91.54
Mean	47.35	48.66	50.04		50.41	51.93	53.64		87.23	89.10	90.94	
SEm±	0.6458				0.5989				0.7082			
CD(0.05)	1.8739				1.7382				2.0552			

Phosphorus and potassium interactions were also found to be significant (Table 4c). The highest plant height was recorded by P_3K_3 for the first crop (41.8 cm, 44.17 cm and 59.28 cm at 30 DAP, 50 DAP and seed harvest stages respectively). In the second crop P_3K_3 recorded plant height of 52.57 cm, 56.13 cm and 93.4 cm at 30 DAP, 50 DAP and seed harvest stage respectively. Here at 30 DAP and at seed harvest stage P_3K_3 was found to be on par with P_3K_2. The lowest plant height was recorded by P_1K_1 (37.96 cm, 38.02 cm and 50.85 cm at 30 DAP, 50 DAP and seed harvest stage respectively for first crop and 45.6 cm, 48.52 cm and 84.93 cm respectively for second crop).

4.1.3 Height of plants with two vegetable harvests

4.1.3.1 Main effects of NPK

The data on the main effects are presented in Table 5 and the analysis of variance in Appendix V.

In both the crops, at all harvest stages highly significant increase in plant height was observed with increase in nitrogen level. The N_3 level of nitrogen recorded the highest plant height at first (30 DAP), second (50 DAP) and seed harvests (47.99 cm, 51.61 cm and 40.7 cm respectively) for the first crop. In the second crop the values were 59.18 cm, 61.54 cm and 63.24 cm respectively at first, second and at seed harvests. The N_3 level was highly significant and was superior to N_2 level of nitrogen which recorded plant height of 40.19 cm, 41.83 cm and 29.61 cm at first, second and at seed harvests respectively. It was 48.04 cm, 50.64 cm and 51.66 cm respectively at first, second and at seed harvest stages of the second crop. The N_2 level of nitrogen was highly significant and was superior to

N_1 level. These values were 32.99 cm, 30.54 cm and 20.42 cm at first, second and at seed harvest stage respectively for the first crop. In the second crop the plant height was 39.34 cm, 40.94 cm and 39.47 cm respectively at first, second and at seed harvests. All the three nitrogen levels were highly significant and were superior to the control which recorded the plant height of 15.2 cm, 15.23 cm and 13.3 cm at first, second and at seed harvests respectively for first crop. In the second crop the values were 18.97 cm, 25.3 cm and 18.42 cm at first, second and at seed harvests respectively.

At all stages of harvests, the three levels of phosphorus recorded higher plant height than the control. The highest plant height was recorded by P_3 level in the first crop (41.61 cm, 43.03 cm and 31.76 cm at first, second and at seed harvest stages respectively) and in the second crop (50.84 cm, 52.93 cm and 53.27 cm respectively). This was followed by P_2 which recorded the plant height of 40.3 cm, 41.35 cm and 30.13 cm at first, second and at seed harvests respectively for the first crop. Similar trend was followed in the second crop (48.89 cm, 51.06 cm and 51.49 cm at first, second and at seed harvests respectively). The P_2 level was superior to P_1 level which recorded a plant height of 39.26 cm, 39.61 cm and 28.84 cm respectively at first, second and at seed harvests of the first crop. The corresponding values for second crop were 46.82 cm, 49.14 cm and 49.61 cm respectively.

The three levels of potassium recorded higher plant height than the control at the harvest stages for both the crops. The highest plant height was recorded by K_3 level for first crop (41.62 cm, 42.77 cm and 31.56 cm at first, second and at seed harvests respectively) and for the second crop (50.30 cm, 52.43 cm and 52.91 cm respectively). The K_3 level was significantly superior to K_2 level which

Table 5. Effect of NPK on the height of plants with two vegetable harvests

	Plant height (cm)					
	First crop			Second crop		
	30 DAP (I harvest)	50 DAP (II harvest)	Seed harvest	30 DAP (I harvest)	50 DAP (II harvest)	Seed harvest
Levels of N (kg ha^{-1})						
50	32.99	30.54	20.42	39.34	40.94	39.47
100	40.19	41.83	29.61	48.04	50.64	51.66
150	47.99	51.61	40.70	59.18	61.54	63.24
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2220	0.2098	0.2419	0.3345	0.22316	0.3286
CD(0.05)	0.6443	0.6087	0.7018	0.9707	0.6475	0.9536
Levels of P_2O_5 (kg ha^{-1})						
50	39.26	39.61	28.84	46.82	49.14	49.61
75	40.30	41.35	30.13	48.89	51.06	51.49
100	41.60	43.03	31.76	50.84	52.93	53.27
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2220	0.2098	0.2419	0.3345	0.2232	0.3286
CD(0.05)	0.6443	0.6087	0.7018	0.9707	0.6475	0.9536
Levels of K_2O (kg ha^{-1})						
50	39.01	39.81	28.97	47.38	49.52	49.94
75	40.53	41.41	30.2	48.87	51.17	51.52
100	41.62	42.77	31.56	50.30	52.43	52.91
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2220	0.2098	0.2419	0.3345	0.2232	0.3286
CD(0.05)	0.6443	0.6087	0.7018	0.9707	0.6475	0.9536

recorded the plant height of 40.53 cm, 41.41 cm and 30.21 cm at first, second and at seed harvests for the first crop while it was 48.87 cm, 51.17 cm and 51.52 cm respectively for second crop. The effect of K_2 level was followed by K_1 level (39.01 cm, 39.81 cm and 28.97 cm at first, second and at seed harvest stages respectively for the first crop). In the second crop the corresponding values were 47.38 cm, 49.52 cm and 49.94 cm respectively.

4.1.3.2 Interaction effects of NPK

At all harvest stages nitrogen and phosphorus interactions were significant for both the crops (Table 6a). The highest plant height was recorded by N_3P_3 (49.72 cm, 53.08 cm and 42.87 cm at first, second and at seed harvests respectively for the first crop). In the second crop the corresponding values were 61.9 cm, 63.6 cm and 65.07 cm respectively. The lowest plant height was recorded by N_1P_1 (31.7 cm, 29.2 cm and 19.52 cm respectively at first, second and at seed harvests of first crop while in the second crop the corresponding values were 37.97 cm, 39.48 cm and 37.37 cm respectively).

Nitrogen and potassium interactions were significant for the crops at all the harvest stages (Table 6b). The N_3K_3 combination recorded the highest plant height of 49.53 cm, 53.05 cm and 42.33 cm at first, second and at seed harvests respectively in the first crop. For the second crop the corresponding values were 60.95 cm, 63.13 cm and 64.75 cm respectively. Here at the seed harvest stage N_3K_3 was found to be on par with N_3K_2. The N_1K_1 combination gave the minimum plant height of 31.78 cm, 29.15 cm and 19.45 cm respectively at first, second and at seed harvest stage for first crop while for the second crop the corresponding values were 38.27 cm, 39.7 cm and 37.83 cm respectively.

Table 6a. Effect of N x P interaction on the height of plants (cm) with two vegetable harvests

Levels of N (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	31.70	33.27	34.00	32.99	29.20	30.28	32.15	30.54	19.52	20.20	21.55	20.42
100	39.63	39.83	41.12	40.19	39.63	42.02	43.85	41.83	28.40	29.57	30.87	29.61
150	46.45	47.80	49.72	47.99	49.98	51.75	53.08	51.61	38.60	40.63	42.87	40.70
Mean	39.26	40.30	41.61		39.61	41.35	43.03		28.84	30.13	31.76	
SEm±	0.3846				0.3636				0.4189			
CD(0.05)	1.116				1.0551				1.2157			
Second crop												
50	37.97	39.65	40.40	39.34	39.48	40.88	42.45	40.94	37.37	39.65	41.40	39.47
100	45.78	48.10	50.23	48.04	48.40	50.78	52.73	50.64	50.00	51.65	53.33	51.66
150	56.72	58.92	61.90	59.18	59.53	61.50	63.60	61.54	61.47	63.18	65.07	63.24
Mean	46.82	48.89	50.84		49.14	51.06	52.93		49.61	51.49	53.27	
SEm±	0.5794				0.3868				0.5692			
CD(0.05)	1.6813				1.1224				1.6518			

Table 6b. Effect of N x K interaction on the height of plants (cm) with two vegetable harvest

Levels of N ($kg\ ha^{-1}$)	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	31.78	33.08	34.10	32.99	29.15	30.52	31.97	30.54	19.45	20.33	21.48	20.42
100	39.20	40.13	41.25	40.19	40.22	42.00	43.28	41.83	28.33	29.65	30.85	29.61
150	46.05	48.38	49.53	47.99	50.05	51.72	53.05	51.61	39.12	40.65	42.33	40.70
Mean	39.01	40.53	41.62		39.81	41.41	42.77		28.97	30.21	31.56	
SEm±	0.3846				0.3636				0.4189			
CD(0.05)	1.116				1.0551				1.2157			
Second crop												
50	38.27	39.25	40.50	39.34	39.70	41.05	42.07	40.94	37.83	39.53	41.05	39.47
100	46.43	48.23	49.45	48.04	49.03	50.78	52.10	50.64	50.27	51.78	52.93	51.66
150	57.45	59.13	60.95	59.18	59.83	61.67	63.13	61.54	61.72	63.25	64.75	63.24
Mean	47.38	48.87	50.30		49.52	51.17	52.43		49.94	51.52	52.91	
SEm±	0.5794				0.3868				0.5692			
CD(0.05)	1.6813				1.1224				1.6518			

Table 6c. Effect of P x K interaction on the height of plants (cm) with two vegetable harvest

Levels of P_2O_5 (kg ha^{-1})	30 days after planting				50 days after planting				Seed harvest stage			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	38.00	39.33	40.45	39.26	38.27	39.55	41.00	39.61	27.70	28.83	29.98	28.84
75	38.67	40.62	41.62	40.30	39.63	41.48	42.93	41.35	28.97	30.05	31.38	30.13
100	40.37	41.65	42.82	41.61	41.52	43.20	44.37	43.03	30.23	31.75	33.30	31.76
Mean	39.01	40.53	41.62		39.81	41.41	42.77		28.97	30.21	31.56	
SEm±	0.3846				0.3636				0.4189			
CD(0.05)	1.116				1.0551				1.2157			
Second crop												
50	45.65	46.87	47.95	46.82	48.07	49.20	50.15	49.14	48.30	49.65	50.88	49.61
75	47.35	48.98	50.33	48.89	49.40	51.08	52.68	51.06	49.90	51.70	52.88	51.49
100	49.15	50.77	52.61	50.84	51.10	53.22	54.47	52.93	51.62	53.22	54.97	53.27
Mean	47.38	48.87	50.30		49.52	51.17	52.43		49.94	51.52	52.91	
SEm±	0.5794				0.3868				0.5692			
CD(0.05)	1.6813				1.1224				1.6518			

Phosphorus and potassium interactions were also significant (Table 6c). The highest plant height was recorded by P_3K_3 for the first crop (42.82 cm, 44.37 cm and 33.3 cm at first, second and at seed harvests respectively) and for second crop (52.61 cm, 54.47 cm and 54.97 cm respectively). The lowest plant height was recorded by P_1K_1 (38 cm, 38.27 cm and 27.7 cm at first, second and at seed harvests respectively for first crop and 45.65 cm, 48.07 cm and 48.3 cm respectively for second crop).

4.2 Green yield

4.2.1 Green yield of plants with one vegetable harvest

4.2.1.1 Main effects of NPK

The data on the main effects are presented in Table 7 and the analysis of variance in Appendix VI.

There was a highly significant increase in green yield with increase in nitrogen level. The N_3 level of nitrogen recorded the highest green yield of 36.53 g/plant and 1223.33 g/plot (7767.2 kg ha^{-1}) for the first crop and it was 53.72 g/plant and 1719.72 g/plot (10918.8 kg ha^{-1}) for the second crop. The N_3 level was highly significant and superior to N_2 level of nitrogen for first crop (26.94 g/plant, 943.6 g/plot and 5991.2 kg ha^{-1}). In the case of second crop the values were 38.39 g/plant, 1305.83 g/plot and 8291 kg ha^{-1}. The N_2 level of nitrogen was also highly significant and was superior to N_1 level which recorded 19.59 g/plant and 4479.72 kg ha^{-1} (705.56 g/plot) for the first crop. In the second crop the green yield recorded was 27.73 g/plant and 6241.62 kg ha^{-1} (983.06 g/plot). All the three nitrogen levels were highly significant and superior to control which recorded an yield of

Table 7. Effect of NPK on the green yield of plants with one vegetable harvest

	Weight of greens					
	First crop			Second crop		
	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Levels of N (kg ha^{-1})						
50	19.59	705.56	4479.72	27.73	983.06	6241.62
100	26.94	943.61	5991.18	38.39	1305.83	8291.00
150	36.53	1223.33	7767.20	53.72	1719.72	10918.80
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
Sem±	0.1982	7.7656	49.305	0.3001	11.5023	73.03
CD(0.05)	0.5752	22.535	143.059	0.8708	33.379	211.93
Levels of P_2O_5 (kg ha^{-1})						
50	26.67	926.39	5881.83	37.00	1290.56	8194.00
75	27.40	952.50	6047.62	40.278	1326.67	8423.28
100	29.00	993.61	6308.64	42.567	1391.39	8834.21
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
Sem±	0.1982	7.7656	49.305	0.3001	11.5023	73.03
CD(0.05)	0.5752	22.535	143.059	0.8708	33.379	211.93
Levels of K_2O (kg ha^{-1})						
50	26.62	923.33	5862.43	37.65	1286.39	8167.55
75	27.76	956.94	6075.83	40.194	1337.50	8492.06
100	28.69	992.22	6299.82	42.00	1384.72	8791.88
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.1982	7.7656	49.305	0.3001	11.5023	73.03
CD(0.05)	0.5752	22.535	143.059	0.8708	33.379	211.93

8.17 g/plant and 220.83 g/plot (1402.1 kg ha^{-1}) for the first crop and 8.67 g/plant and 279.17 g/plot (1772.5 kg ha^{-1}) in the second crop.

The three levels of phosphorus recorded higher green yield than the control for both the crops. The highest green yield was recorded by P_3 level for the first crop (29.0 g/plant, 993.6 g/plot and 6308.64 kg ha^{-1}) and for the second crop (42.57 g/plant, 1391.39 g/plot and 8834.21 kg ha^{-1}). The P_3 level was significantly superior to P_2 level which recorded a green yield of 27.4 g/plant and 952.5 g/plot (6047.62 kg ha^{-1}) for the first crop while it was 40.28 g/plant and 8423.28 kg ha^{-1} (1326.67 g/plot) for the second crop. The effect of P_2 level was followed by P_1 level which recorded a green yield of 26.67 g/plant and 926.39 g/plot (5881.83 kg ha^{-1}) for the first crop. In the second crop the green yield recorded was 37 g/plant and 1290.56 g/plot (8194 kg ha^{-1}).

The potassium levels also yielded more than the control for both crops. The K_3 level recorded the highest green yield of 28.69 g/plant and 992.22 g/plot (6299.82 kg ha^{-1}) in the first crop. In the second crop it was 42.0 g/plant and 1384.72 g/plot (8791.88 kg ha^{-1}). This was followed by K_2 which recorded the green yield of 27.76 g/plant and 6075.83 kg ha^{-1} (956.94 g/plot) for first crop. Similar was the trend with the second crop also (40.19 g/plant, 1337.5 g/plot and 8492.06 kg ha^{-1}). The K_2 level was superior to K_1 level which recorded a green yield of 26.62 g/plant and 5862.43 kg ha^{-1} (923.33 g/plot) for first crop. For the second crop the green yields were 37.65 g/plant, 1286.39 g/plot and 8167.55 kg ha^{-1}.

4.2.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops

Table 8a. Effect of N x P interaction on the green yield of plants with one harvest

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	19.17	19.53	20.08	19.59	683.33	702.50	730.83	705.56	4338.62	4460.32	4640.21	4479.70
100	26.33	26.92	27.58	26.94	920.83	945.00	965.00	943.61	5846.56	6000.00	6126.98	5991.18
150	34.52	35.75	39.33	36.53	1175.00	1210.00	1285.00	1223.33	7460.32	7682.54	8158.73	7767.20
Mean	26.67	27.40	29.00		926.39	952.50	993.61		5881.83	6047.62	6308.64	
SEm±	0.34336				13.45				85.3982			
CD(0.05)	0.996				39.03				247.82			
Second crop												
50	27.00	27.75	28.45	27.73	966.67	979.17	1003.33	983.06	6137.60	6216.90	6370.40	6241.62
100	36.75	38.17	40.25	38.39	1259.17	1308.33	1350.00	1305.83	7994.70	8306.90	8571.40	8291.00
150	47.25	54.92	59.00	53.72	1645.83	1692.50	1820.83	1719.72	10449.70	10746.00	11560.80	10918.80
Mean	37.00	40.278	42.567		1290.56	1326.67	1391.39		8194.00	8423.28	8834.20	
SEm±	0.5198				19.923				126.49			
CD(0.05)	1.508				57.814				367.07			

Table 8b. Effect of N x K interaction on the green yield of plants with one harvest

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	19.17	19.62	20.00	19.59	683.33	704.17	729.17	705.56	4338.60	4470.90	4629.63	4479.72
100	26.25	26.92	27.67	26.94	912.50	945.83	972.50	943.61	5793.65	6005.29	6174.60	5991.18
150	34.43	36.75	38.42	36.53	1174.17	1220.83	1275.00	1223.33	7455.03	7751.32	8095.24	7767.20
Mean	26.62	27.76	28.69		923.33	956.94	992.22		5862.43	6075.84	6299.82	
SEm±	0.3434				13.45				85.398			
CD(0.05)	0.996				39.03				247.82			
Second crop												
50	26.95	27.83	28.42	27.73	950.00	983.33	1015.83	983.06	6031.70	6243.40	6449.70	6241.62
100	37.00	38.25	39.92	38.39	1262.50	1304.17	1350.83	1305.83	8015.90	8280.40	8576.70	8291.00
150	49.00	54.50	57.67	53.72	1646.67	1725.00	1787.50	1719.72	10455.00	10952.40	11349.20	10918.80
Mean	37.65	40.19	42.00		1286.39	1337.50	1384.72		8167.55	8492.06	8791.88	
SEm±	0.5198				19.923				126.49			
CD(0.05)	1.5084				57.814				367.07			

Table 8c. Effect of P x K interaction on the green yield of plants with one vegetable harvest

Levels of P_2O_5 (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	26.02	26.67	27.33	26.67	904.17	920.83	954.17	926.39	5740.74	5846.56	6058.20	5881.83
75	26.42	27.45	28.33	27.40	922.50	954.17	980.83	952.50	5857.14	6058.20	6227.50	6047.62
100	27.42	29.17	30.42	29.00	943.30	995.80	1041.67	993.60	5989.42	6322.75	6613.76	6308.64
Mean	26.62	27.76	28.69		923.30	956.94	992.22		5862.43	6075.84	6299.82	
SEm±	0.3434				13.45				85.398			
CD(0.05)	0.996				39.03				247.82			
Second crop												
50	33.83	37.83	39.33	37.00	1254.17	1295.83	1321.67	1290.56	7963.00	8227.50	8391.50	8194.00
75	38.50	40.167	42.167	40.278	1284.17	1320.83	1375.00	1326.67	8153.40	8386.20	8730.20	8423.28
100	40.617	42.583	44.50	42.567	1320.83	1395.83	1457.50	1391.39	8386.20	8862.40	9254.00	8834.21
Mean	37.65	40.194	42.00		1286.39	1337.50	1384.72		8167.55	8492.06	8791.88	
SEm±	0.5198				19.923				126.49			
CD(0.05)	1.508				57.814				367.07			

(Table 8a). The N_3P_3 combination recorded the highest green yield of 39.33 g/plant and 993.61 g/plot (6308.64 kg ha^{-1}) in the first crop. For the second crop the corresponding values were 59.0 g/plant and 1820.83 g/plot (11560.8 kg ha^{-1}). The N_1P_1 combination gave the minimum green yield of 19.17 g/plant and 683.33 g/plot (4338.62 kg ha^{-1}) for first crop while in the second crop the corresponding yields were 27.0 g/plant and 966.67 g/plot and 6137.6 kg ha^{-1}.

The nitrogen and potassium interactions were also significant for green yield in both the crops (Table 8b). The highest green yield was recorded by N_3K_3 for first crop (38.42 g/plant, 8095.24 kg ha^{-1} and 1275.0 g/plot) and in the second crop (57.67 g/plant, 1787.5 g/plot and 11349.2 kg ha^{-1}). The lowest green yield was recorded by N_1K_1 for the first crop (19.17 g/plant, 683.33 g/plot and 4338.6 kg ha^{-1}) and for second crop (26.95 g/plant, 950 g/plot and 6031.7 kg ha^{-1}).

Phosphorus and potassium interactions were also found to be significant (Table 8c). The highest green yield was recorded by P_3K_3 for the first crop (30.42 g/plant, 1041.67 g/plot and 6613.76 kg ha^{-1}) and for second crop (44.5 g/plant, 1457.5 g/plot and 9254.0 kg ha^{-1}). The P_1K_1 combination recorded the lowest green yield of 26.02 g/plant, 904.17 g/plot and 5740.74 kg ha^{-1} for first crop. For second crop the values were 33.83 g/plant, 1254.17 g/plot and 7963.0 kg ha^{-1}.

4.2.3 Green yield of plants with two vegetable harvests

4.2.3.1 Green yield at first harvest

4.2.3.1.1 Main effects of NPK

The data on the main effects are presented in Table 9 and the analysis of variance in Appendix VII.

There was a highly significant increase in green yield with increase in nitrogen level in both the crops. The N_3 level of nitrogen recorded the highest green yield for first crop (37.19 g/plant, 1278.06 g/plot and 8114.6 kg ha^{-1}). In the second crop the green yields were 52.61 g/plant, 1787.78 g/plot and 11351.0 kg ha^{-1}. the N_3 level was highly significant and was superior to N_2 level which recorded a green yield of 27.69 g/plant, 982.22 g/plot and 6236.3 kg ha^{-1} for the first crop. It was 36.53 g/plant, 1286.11 g/plot and 8165.8 kg ha^{-1} for second crop. The N_2 level of nitrogen was highly significant and superior to N_1 level. Their values were 19.72 g/plant, 708.06 g/plot and 4495.6 kg ha^{-1} for first crop while it was 27.86 g/plant, 1003.6 g/plot and 6372.1 kg ha^{-1} for second crop. All the three nitrogen levels were highly significant and superior to the control which recorded a green yield of 9.75 g/plant, 183.3 g/plot and 1164.02 kg ha^{-1} for first crop. In the second crop the yields were 10.25 g/plant, 266.7 g/plot and 1693.12 kg ha^{-1}.

The three levels of phosphorus recorded higher green yield than the control. The highest green yield was recorded by P_3 level in the first crop (29.61 g/plant, 1039.44 g/plot and 6599.6 kg ha^{-1}) and in the second crop (41.06 g/plant, 1415.83 g/plot and 8989.4 kg ha^{-1}). This was followed by P_2 which recorded green yield of 28.14 g/plant, 986.67 g/plot and 6264.6 kg ha^{-1} for first crop. Similar trend was observed in the second crop (38.97 g/plant, 1357.22 g/plot and 8617.3 kg ha^{-1}). The P_2 level was superior to P_1 level which recorded a green yield of 26.86 g/plant, 942.22 g/plot and 5982.4 kg ha^{-1} for the first crop. The corresponding values for second crop were 36.97 g/plant, 1304.45 g/plot and 8282.2 kg ha^{-1}.

The three levels of potassium recorded higher green yield than the control for both the crops. The highest green yield was recorded by K_3 level for first

Table 9. Effect of NPK on the green yield at first harvest from plants given two vegetable harvests

	Weight of greens					
	First crop			Second crop		
	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Levels of N (kg ha^{-1})						
50	19.72	708.06	4495.60	27.86	1003.61	6372.10
100	27.69	982.22	6236.30	36.53	1286.11	8165.80
150	37.19	1278.06	8114.60	52.61	1787.78	11351.00
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2948	10.4824	66.554	0.2777	9.7619	61.979
CD(0.05)	0.8554	30.42	193.135	0.80589	28.328	179.86
Levels of P_2O_5 (kg ha^{-1})						
50	26.86	942.22	5982.40	36.97	1304.45	8282.20
75	28.14	986.67	6264.60	38.97	1357.22	8617.30
100	29.61	1039.44	6599.60	41.06	1415.83	8989.40
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2948	10.4824	66.554	0.2777	9.7619	61.979
CD(0.05)	0.8554	30.42	193.135	0.80589	28.328	179.86
Levels of K_2O (kg ha^{-1})						
50	26.81	945.83	6005.30	37.36	1305.83	8291.00
75	28.31	986.94	6266.30	39.03	1361.95	8647.30
100	29.50	1035.56	6575.00	40.61	1409.72	8950.60
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.2948	10.4824	66.554	0.2777	9.7619	61.979
CD(0.05)	0.8554	30.42	193.135	0.80589	28.328	179.86

crop (29.5 g/plant, 1035.56 g/plot and 6575.0 kg ha^{-1}) and second crop (40.6 g/plant, 1409.72 g/plot and 8950.6 kg ha^{-1}). The K_3 level was significantly superior to K_2 level which recorded green yield of 28.31 g/plant, 986.94 g/plot and 6266.3 kg ha^{-1} for first crop while it was 39.03 g/plant, 1361.95 g/plot and 8647.3 kg ha^{-1} for second crop. The effect of K_2 level was followed by K_1 level (26.81 g/plant, 945.83 g/plot and 6005.3 kg ha^{-1}) for the first crop and for the second crop (37.36 g/plant, 1305.83 g/plot and 8291.9 kg ha^{-1}).

4.2.3.1.2 Interaction effects of NPK

The interaction effects of nitrogen and phosphorus were significant (Table 10a). The highest green yield was recorded by N_3P_3 for the first crop (40.42 g/plant, 1354.17 g/plot and 8597.9 kg ha^{-1}) and for the second crop (56.50 g/plant, 1884.17 g/plot and 11963.0 kg ha^{-1}). The lowest green yield was recorded by N_1P_1 (19.08 g/plant, 668.33 g/plot and 4243.4 kg ha^{-1} for first crop and 27.33 g/plant, 967.5 g/plot and 6142.9 kg ha^{-1} for the second crop).

Nitrogen and potassium interactions were also significant (Table 10b). The N_3K_3 combination recorded the highest green yield of 39.42 g/plant, 1335.83 g/plot and 8481.5 kg ha^{-1} in the first crop. For the second crop the values were 55.50 g/plant, 1845.83 g/plot and 11719.6 kg ha^{-1}. The N_1K_1 combination gave the minimum green yield of 18.92 g/plant, 670.83 g/plot and 4259.3 kg ha^{-1} for first crop. In the second crop the values were 27.25 g/plant, 955.0 g/plot and 6063.5 kg ha^{-1}.

Phosphorus and potassium interactions were also found significant (Table 10c). The highest green yield was recorded by P_3K_3 for the first crop (31.33 g/plant, 1087.5 g/plot and 6904.8 kg ha^{-1}) and for second crop (42.83

Table 10a. Effect of N x P interaction on the green yield at first harvest from plants given two vegetable harvests

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	19.08	19.75	20.33	19.72	668.33	708.33	747.50	708.06	4243.4	4497.4	4746.0	4495.6
100	27.33	27.67	28.08	27.69	941.67	988.33	1016.67	982.22	5978.8	6275.1	6455.0	6236.3
150	34.17	37.00	40.42	37.19	1216.67	1263.33	1354.17	1278.06	7724.9	8021.2	8597.9	8114.6
Mean	26.86	28.14	29.61		942.22	986.67	1039.44		5982.4	6264.6	6599.6	
SEm±	0.5106				18.156				115.2747			
CD(0.05)	1.482				52.688				334.52			
Second crop												
50	27.33	28.00	28.25	27.86	967.50	996.67	1046.67	1003.61	6142.9	6328.0	6645.5	6372.1
100	34.75	36.42	38.42	36.53	1250.00	1291.67	1316.67	1286.11	7936.5	8201.1	8359.8	8165.8
150	48.83	52.50	56.50	52.61	1695.83	1783.33	1884.17	1787.78	10767.2	11322.8	11963.0	11351.0
Mean	36.97	38.97	41.06		1304.45	1357.22	1415.83		8282.2	8617.3	8989.4	
SEm±	0.481				16.908				107.352			
CD(0.05)	1.396				49.066				311.53			

Table 10b. Effect of N x K interaction on the green yield at first harvest from plants given two vegetable harvests

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	18.92	19.67	20.58	19.72	670.83	707.50	745.83	708.06	4259.3	4492.1	4735.5	4495.6
100	26.83	27.75	28.50	27.69	941.67	980.00	1025.00	982.22	5978.8	6222.2	6507.9	6236.3
150	34.67	37.50	39.42	37.19	1225.00	1273.33	1335.83	1278.06	7777.8	8084.7	8481.5	8114.6
Mean	26.81	28.31	29.50		945.83	986.94	1035.56		6005.3	6266.3	6575.0	
SEm±	0.5106				18.156				115.2747			
CD(0.05)	1.482				52.688				334.52			
Second crop												
50	27.25	27.83	28.50	27.86	955.00	1005.83	1050.00	1003.61	6063.5	6386.2	6666.7	6372.1
100	35.08	36.67	37.83	36.53	1237.50	1287.50	1333.33	1286.11	7857.1	8174.6	8465.6	8165.8
150	49.75	52.58	55.50	52.61	1725.00	1792.50	1845.83	1787.78	10952.4	11381.0	11719.6	11351.0
Mean	37.36	39.03	40.61		1305.83	1361.95	1409.72		8291.0	8647.3	8950.6	
SEm±	0.481				16.908				107.352			
CD(0.05)	1.396				49.066				311.53			

Table 10c. Effect of P x K interaction on the green yield at first harvest from plants given two vegetable harvests

Levels of P_2O_5 (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	26.00	26.83	27.75	26.86	900.00	941.67	985.00	942.22	5714.3	5978.8	6254.0	5982.4
75	26.58	28.42	29.42	28.14	937.50	988.33	1034.17	986.67	5952.4	6275.1	6566.1	6264.6
100	27.83	29.67	31.33	29.61	1000.00	1030.83	1087.50	1039.44	6349.2	6545.0	6904.8	6599.6
Mean	26.81	28.31	29.50		945.83	986.94	1035.56		6005.3	6266.3	6575.0	
SEm±	0.5106				18.156				115.2747			
CD(0.05)	1.482				52.688				334.52			
Second crop												
50	35.75	36.92	38.25	36.97	1254.17	1309.167	1350.00	1304.45	7963.0	8312.2	8571.4	8282.2
75	37.25	38.92	40.75	38.97	1304.17	1359.17	1408.33	1357.22	8280.4	8629.6	8941.8	8617.3
100	39.08	41.25	42.83	41.06	1359.17	1417.5	1470.83	1415.83	8629.6	9000.0	9338.6	8989.4
Mean	37.36	39.03	40.61		1305.83	1361.95	1409.72		8282.2	8617.3	8989.4	
SEm±	0.481				16.908				107.352			
CD(0.05)	1.396				49.066				311.53			

g/plant, 1470.83 g/plot and 9338.6 kg ha^{-1}). The minimum green yield was recorded by P_1K_1 for first crop (26.0 g/plant, 900.0 g/plot and 5714.3 kg ha^{-1}) and for the second crop (35.75 g/plant, 1254.17 g/plot and 7963.0 kg ha^{-1}).

4.2.3.2 Green yield at second harvest

4.2.3.2.1 Main effects of NPK

The data on the main effects are presented in Table 11 and the analysis of variance in Appendix VIII.

There was a highly significant increase in green yield with increase in nitrogen level. The N_3 level of nitrogen recorded the highest green yield of 83.33 g/plant, 2448.61 g/plot and 15546.7 kg ha^{-1} for the first crop and it was 109.78 g/plant, 2861.94 g/plot and 18171.0 kg ha^{-1} for second crop. The N_3 level was highly significant and was superior to N_2 level of nitrogen for the first crop (58.44 g/plant, 1796.94 g/plot and 11409.2 kg ha^{-1}). In the case of second crop the yields were 79.67 g/plant, 2018.06 g/plot and 12813.1 kg ha^{-1}. The N_2 level of nitrogen was highly significant and superior to N_1 level which recorded 35.5 g/plant, 1246.11 g/plot and 7911.8 kg ha^{-1} for the first crop. In the second crop the green yields were 56.37 g/plant, 1418.89 g/plot and 9008.8 kg ha^{-1}. All the three nitrogen levels were highly significant and superior to the control which recorded a green yield of 14.58 g/plant, 386.67 g/plot and 2455.03 kg ha^{-1} for the first crop. In the second crop the yields were 17.58 g/plant, 495.83 g/plot and 3148.1 kg ha^{-1}.

The three levels of phosphorus recorded higher green yield than the control for both the crops. The highest green yield was recorded by P_3 level for the first crop (63.08 g/plant, 1915.28 g/plot and 12160.5 kg ha^{-1}) and also for the second

Table 11. Effect of NPK on the green yield at second harvest from plants given two vegetable harvest

	Weight of greens					
	First crop			Second crop		
	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Levels of N (kg ha^{-1})						
50	35.50	1246.11	7911.80	56.37	1418.89	9008.80
100	58.44	1796.94	11409:20	79.67	2018.06	12813.10
150	83.33	2448.61	15546.70	109.78	2861.94	18171.00
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.4635	14.9806	95.114	0.644	14.229	90.342
CD(0.05)	1.345	43.47	276.02	1.8689	41.292	262.17
Levels of P_2O_5 (kg ha^{-1})						
50	55.28	1728.89	10977.10	78.06	2036.39	12929.50
75	58.92	1847.50	11730.20	81.67	2087.50	13254.00
100	63.08	1915.28	12160.50	86.08	2175:00	13810.00
'F' test	Sig..	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.4635	14.9806	95.114	0.644	14.229	90.342
CD(0.05)	1.345	43.47	276.02	1.8689	41.292	262.17
Levels of K_2O (kg ha^{-1})						
50	56.39	1758.33	11164.00	78.53	2031.39	12897.70
75	59.06	1831.95	11631.40	81.92	2097.22	13315.70
100	61.83	1901.39	12072.30	85.37	2170.28	13779.60
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.4635	14.9806	95.114	0.644	14.229	90.342
CD(0.05)	1.345	43.47	276.02	1.8689	41.292	262.17

crop (86.08 g/plant, 2175.0 g/plot and 13810.0 kg ha^{-1}). The P_3 level was significantly superior to P_2 level which recorded a green yield of 58.92 g/plant, 1847.5 g/plot and 11730.2 kg ha^{-1} for the first crop and it was 81.67 g/plant, 2087.5 g/plot and 13254.0 kg ha^{-1} for the second crop. The effect of P_2 level was followed by P_1 level which recorded an yield of 55.28 g/plant, 1728.89 g/plot and 10977.1 kg ha^{-1} for the first crop. In the second crop the yields were 78.06 g/plant, 2036.39 g/plot and 12929.5 kg ha^{-1}.

The potassium levels also recorded higher green yield than the control for both the crops. The K_3 level recorded the highest green yield of 61.83 g/plant, 1901.39 g/plot and 12072.3 kg ha^{-1} in the first crop. In the second crop it was 85.37 g/plant, 2170.28 g/plot and 13779.6 kg ha^{-1}. This was followed by K_2 level which recorded a green yield of 59.06 g/plant, 1831.95 g/plot and 11631.4 kg ha^{-1} for the first crop. Similar trend was observed with second crop also (81.92 g/plant, 2097.22 g/plot and 12897.7 kg ha^{-1}). The K_2 level was superior to K_1 level which recorded a green yield of 56.39 g/plant, 1758.33 g/plot and 11164.0 kg ha^{-1}) for first crop. For the second crop the yields were 78.53 g/plant, 2031.39 g/plot and 12897.7 kg ha^{-1}.

4.2.3.2.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops (Table 12a). The N_3P_3 combination recorded the highest green yield of 88.33 g/plant, 2566.67 g/plot and 16296.3 kg ha^{-1} for the first crop. For the second crop the corresponding values were 114.17 g/plant, 2945.83 g/plot and 18703.7 kg ha^{-1}. The N_1P_1 combination gave minimum green yield of 32.83 g/plant, 1166.67 g/plot and 7407.4 kg ha^{-1} for first crop and for the second crop the yields were 54.33 g/plant, 1390.0 g/plot and 8825.4 kg ha^{-1}.

Table 12a. Effect of N x P interaction on the green yield at second harvest from plants given two vegetable harvests

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	32.83	35.00	38.67	35.50	1166.67	1271.67	1300.00	1246.11	7407.4	8074.1	8254.0	7911.8
100	54.50	58.58	62.25	58.44	1699.17	1812.50	1879.17	1796.94	10788.4	11508.0	11931.2	11409.2
150	78.50	83.17	88.33	83.33	2320.83	2458.33	2566.67	2448.61	14735.5	15608.5	16296.3	15546.7
Mean	55.28	58.92	63.08		1728.89	1847.50	1915.28		10977.1	11730.2	12160.5	
SEm±	0.8028				25.947				164.742			
CD(0.05)	2.33				75.297				478.072			
Second crop												
50	54.33	56.18	58.58	56.37	1390.00	1408.33	1458.33	1418.89	8825.4	8941.8	9259.3	9008.8
100	74.50	79.00	85.50	79.67	1933.33	2000.00	2120.83	2018.06	12275.1	12698.4	13465.6	12813.1
150	105.33	109.83	114.17	109.78	2785.83	2854.17	2945.83	2861.94	17687.8	18121.7	18703.7	18171.0
Mean	78.06	81.67	86.08		2036.39	2087.50	2175.00		12929.5	13254.0	13810.0	
SEm±	1.1155				24.645				156.48			
CD(0.05)	3.237				71.52				454.09			

Table 12b. Effect of N x K interaction on the green yield at second harvest from plants given two vegetable harvests

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	33.50	35.42	37.58	35.50	1196.67	1258.33	1283.33	1246.11	7597.9	7989.4	8148.1	7911.8
100	56.00	58.17	61.17	58.44	1724.17	1787.50	1879.17	1796.94	10947.1	11349.2	11931.2	11409.2
150	79.67	83.58	86.75	83.33	2354.17	2450.00	2541.67	2448.61	14947.1	15555.6	16137.6	15546.7
Mean	56.39	59.06	61.83		1758.33	1831.95	1901.39		11164.0	11631.4	12072.3	
SEm±	0.8028				25.947				164.742			
CD(0.05)	2.33				75.297				478.072			
Second crop												
50	54.33	56.25	58.52	56.37	1366.67	1412.50	1477.50	1418.89	8677.2	8968.3	9381.0	9008.8
100	75.33	79.50	84.17	79.67	1941.67	2016.67	2095.83	2018.06	12328.0	12804.2	13306.9	12813.1
150	105.92	110.00	113.42	109.78	2785.83	2862.50	2937.50	2861.94	17687.8	18174.6	18650.8	18171.0
Mean	78.53	81.92	85.37		2031.39	2097.22	2170.28		12897.7	13315.7	13779.6	
SEm±	1.1155				24.645				156.48			
CD(0.05)	3.237				71.52				454.09			

Table 12c. Effect of P x K interaction on the green yield at second harvest from plants given two vegetable harvests

Levels of P_2O_5 (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	53.08	55.25	57.50	55.28	1657.50	1725.00	1804.17	1728.89	10523.8	10952.4	11455.0	10977.1
75	56.58	58.83	61.33	58.92	1780.00	1858.33	1904.17	1847.50	11301.6	11799.0	12090.0	11730.2
100	59.50	63.08	66.67	63.08	1837.50	1912.50	1995.83	1915.28	11666.7	12142.9	12672.0	12160.5
Mean	56.39	59.06	61.83		1758.33	1831.95	1901.39		11164.0	11631.4	12072.3	
SEm±	0.8028				25.947				164.742			
CD(0.05)	2.33				75.297				478.072			
Second crop												
50	75.08	78.00	81.083	78.06	1990.0	2029.17	2090.0	2036.39	12634.9	12883.6	13269.8	12929.5
75	78.17	82.00	84.85	81.67	2008.33	2087.50	2166.67	2087.50	12751.3	13254.0	13756.6	13254.0
100	82.33	85.75	90.17	86.08	2095.83	2175.0	2254.17	2175.0	13306.9	13809.5	14312.2	13810.0
Mean	78.53	81.92	85.37		2031.39	2097.22	2170.28		12897.7	13315.7	13779.6	
SEm±	1.1155				24.645				156.48			
CD(0.05)	3.237				71.52				454.09			

The nitrogen and potassium interactions were significant for both the crops with respect to green yield (Table 12b). The highest green yield was recorded by N_3K_3 for first crop (86.75 g/plant, 2541.67 g/plot and 16137.6 kg ha^{-1}) and for the second crop (113.42 g/plant, 2937.5 g/plot and 18650.8 kg ha^{-1}). The lowest green yield was recorded by N_1K_1 for both the crops (33.5 g/plant, 1196.67 g/plot and 7597.9 kg ha^{-1} for the first crop and 54.33 g/plant, 1366.67 g/plot and 8677.2 kg ha^{-1} for the second crop).

Phosphorus and potassium interactions were also found to be significant (Table 12c). The highest yield was recorded by P_3K_3 for the first crop (66.67 g/plant, 1995.83 g/plot and12672.0 kg ha^{-1}) and also for the second crop (90.17 g/plant, 2254.17 g/plot and 14312.2 kg ha^{-1}). The P_1K_1 combination recorded the lowest green yield of 53.08 g/plant, 1657.5 g/plot and 10523.8 kg ha^{-1} for first crop and for the second crop 75.08 g/plant, 1990.0 g/plot and 12634.9 kg ha^{-1}.

4.3 Quality of greens

4.3.1 Oxalate content

4.3.1.1 Oxalate content of plants with one vegetable harvest

4.3.1.1.1 Main effects of NPK

The data on the main effects are presented in Table 13 and the analysis of variance in Appendix IX.

The oxalate content was found decreasing at a significant level with the increase in nitrogen levels. The N_3 level of nitrogen recorded the lowest oxalate content of 5.34 per cent for the first crop and 5.85 per cent for the second crop. The

Table 13. Effect of nitrogen, phosphorus and potassium on oxalate content (%)

	Oxalate content of plants with one vegetable harvest		Oxalate content of plants with two vegetable harvests			
			First crop		Second crop	
	First crop	Second crop	First harvest	Second harvest	First harvest	Second harvest
Levels of N (kg ha^{-1})						
50	6.30	6.79	6.29	5.76	6.79	6.29
100	5.80	6.30	5.81	5.32	6.31	5.85
150	5.34	5.85	5.35	4.84	5.87	5.37
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.00953	0.0103	0.009111	0.005316	0.009614	0.008838
CD(0.05)	0.0277	0.0300	0.02644	0.01543	0.0279	0.02565
Levels of P_2O_5 (kg ha^{-1})						
50	5.993	6.49	5.99	5.44	6.50	5.96
75	5.804	6.31	5.81	5.32	6.31	5.83
100	5.641	6.15	5.65	5.16	6.16	5.71
'F' test	Sig..	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.00953	0.0103	0.009111	0.005316	0.009614	0.008838
CD(0.05)	0.0277	0.03	0.02644	0.01543	0.0279	0.02565
Levels of K_2O (kg ha^{-1})						
50	5.70	6.20	5.71	5.21	6.21	5.75
75	5.80	6.31	5.81	5.30	6.31	5.87
100	5.94	6.44	5.94	5.40	6.45	5.95
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.00953	0.0103	0.009111	0.005316	0.009614	0.008838
CD(0.05)	0.0277	0.03	0.02644	0.01543	0.0279	0.02565

N_3 level effected lower level of oxalate than N_2 level (5.8% for the first crop and 6.3% for the second crop) and the effect was found highly significant. The N_1 values were higher than N_2 which recorded 6.3 per cent for first crop and 6.79 per cent for second crop. The control recorded the highest value for oxalate content in the first and second crops (6.86% and 7.3% respectively).

The oxalate content was found to decrease significantly with increase in the phosphorus levels. All the three levels of phosphorus recorded significantly lower oxalate content than the control for both the crops. The lowest oxalate content was recorded by the P_3 level for the first crop (5.64%) and for the second crop (6.15%). There was significant difference between phosphorus levels. P_2 level recorded an oxalate content of 5.8 per cent for first crop and 6.31 per cent for second crop and P_1 level recorded an oxalate content of 5.99 per cent for first crop and 6.49 per cent for second crop.

There was significant increase in the oxalate content with increase in the potassium levels also. All the three levels of potassium recorded significantly lower oxalate content than the control for both the crops. For the first crop, K_1 level recorded the lowest oxalate content of 5.7 per cent and for the second crop it was 6.2 per cent. The effect of K_1 was followed by K_2 (5.8% and 6.31% for first and second crops respectively) and K_3 (5.94% for first crop and 6.44% for second crop).

4.3.1.1.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops (Table 14a). The N_3P_3 combination recorded the lowest oxalate content of 5.18 per cent for the first crop and 5.7 per cent for the second crop. The N_1P_1 combination

Table 14a. Effect of N x P interaction on the oxalate content (%)

Levels of N (kg ha^{-1})	Plants with one vegetable harvest (30 DAP)				Plants with two vegetable harvests							
					First harvest (30 DAP)				Second harvest (50 DAP)			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	6.45	6.30	6.14	6.30	6.44	6.30	6.14	6.29	5.88	5.80	5.61	5.76
100	6.00	5.80	5.61	5.80	5.99	5.81	5.62	5.81	5.44	5.34	5.17	5.32
150	5.53	5.31	5.18	5.34	5.54	5.32	5.19	5.35	5.00	4.81	4.72	4.84
Mean	5.993	5.804	5.641		5.99	5.81	5.65		5.44	5.32	5.16	
SEm±	0.0165				0.01578				0.009207			
CD(0.05)	0.04789				0.0458				0.02672			
Second crop												
50	6.94	6.80	6.65	6.79	6.93	6.80	6.64	6.79	6.41	6.30	6.15	6.29
100	6.50	6.31	6.10	6.30	6.51	6.32	6.11	6.31	5.97	5.87	5.72	5.85
150	6.05	5.81	5.70	5.85	6.07	5.83	5.71	5.87	5.51	5.34	5.27	5.37
Mean	6.49	6.31	6.15		6.50	6.31	6.16		5.96	5.83	5.71	
SEm±	0.0179				0.01665				0.01531			
CD(0.05)	0.05199				0.04832				0.0444			

Table 14b. Effect of N x K interaction on the oxalate content (%)

Levels of N ($kg\ ha^{-1}$)	Plants with one vegetable harvest (30 DAP)				Plants with two vegetable harvests							
					First harvest (30 DAP)				Second harvest (50 DAP)			
	Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	6.19	6.30	6.41	6.30	6.19	6.29	6.40	6.29	5.64	5.76	5.87	5.76
100	5.69	5.79	5.93	5.80	5.69	5.80	5.93	5.81	5.24	5.31	5.40	5.32
150	5.22	5.32	5.47	5.34	5.24	5.33	5.48	5.35	4.74	4.84	4.94	4.84
Mean	5.70	5.80	5.94		5.71	5.81	5.94		5.21	5.30	5.40	
SEm±	0.0165				0.01578				0.009207			
CD(0.05)	0.04789				0.0458				0.02672			
Second crop												
50	6.67	6.79	6.92	6.79	6.66	6.79	6.91	6.79	6.15	6.29	6.43	6.29
100	6.19	6.30	6.42	6.30	6.21	6.31	6.43	6.31	5.75	5.85	5.95	5.85
150	5.74	5.84	5.98	5.85	5.76	5.84	6.01	5.87	5.26	5.37	5.47	5.37
Mean	6.20	6.31	6.44		6.21	6.31	6.45		5.75	5.87	5.95	
SEm±	0.01792				0.01665				0.0153			
CD(0.05)	0.05199				0.04832				0.0444			

Table 14c. Effect of P x K interaction on the oxalate content (%)

Levels of P_2O_5 (kg ha^{-1})	Plants with one vegetable harvest (30 DAP)				Plants with two vegetable harvests							
	Levels of K_2O (kg ha^{-1})				First harvest (30 DAP)				Second harvest (50 DAP)			
					Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	5.89	5.98	6.11	5.993	5.89	5.98	6.10	5.99	5.32	5.44	5.55	5.44
75	5.70	5.79	5.92	5.804	5.71	5.80	5.92	5.81	5.23	5.30	5.42	5.32
100	5.50	5.64	5.78	5.641	5.52	5.65	5.78	5.65	5.07	5.17	5.25	5.16
Mean	5.70	5.80	5.94		5.71	5.81	5.94		5.21	5.30	5.40	
SEm±	0.0165				0.01578				0.009207			
CD(0.05)	0.04789				0.0458				0.02672			
Second crop												
50	6.38	6.48	6.63	6.49	6.38	6.48	6.66	6.50	5.84	5.96	6.09	5.96
75	6.20	6.30	6.42	6.31	6.21	6.31	6.42	6.31	5.73	5.83	5.95	5.83
100	6.02	6.16	6.29	6.15	6.03	6.16	6.27	6.16	5.60	5.72	5.81	5.71
Mean	6.20	6.31	6.44		6.21	6.31	6.45		5.75	5.87	5.95	
SEm±	0.01792				0.01665				0.01531			
CD(0.05)	0.05199				0.04832				0.0444			

recorded the highest oxalate content of 6.45 per cent and 6.94 per cent for first and second crops respectively.

The nitrogen and potassium interactions were found significant in the oxalate content of plant (Table 14b). The N_3K_1 combination gave the minimum oxalate content of 5.22 per cent for the first crop and 5.74 per cent for the second crop. The maximum oxalate content was recorded under N_1K_3 for the first crop (6.41%) and for the second crop (6.92%).

Phosphorus and potassium interaction was also found to be significant (Table 14c). The lowest oxalate content was recorded by P_3K_1 in both the crops (5.5% for first crop and 6.02% for second crop). The P_1K_3 combination recorded the highest oxalate content of 6.11 per cent for first crop and 6.63 per cent for the second crop.

4.3.1.2 Oxalate content of plants with two vegetable harvests

4.3.1.2.1 Main effects of NPK

The data on the main effects are presented in Table 13 and the analysis of variance in Appendix IX.

The oxalate content decreased at a significant level with the increase in nitrogen levels. The N_3 level of nitrogen recorded the lowest oxalate content of 5.35 per cent and 4.84 per cent at first and second harvests respectively for the first crop. In the case of second crop the values were 5.87 per cent and 5.37 per cent respectively at first and second harvests. The N_2 level effected significantly higher oxalate content (5.81% and 5.32% at first and second harvests respectively) than N_3 level for the first crop and for the second crop (6.31% and 5.85% respectively). The effect of N_1 level was higher than N_2 level for the first crop (6.29% at first harvest and 5.76% at second harvest) as well as for second crop (6.79% at first harvest and 6.29% at second harvest). All the three nitrogen levels recorded significantly lower oxalate content than the control for first crop (6.85% and 6.2% at first and second harvests respectively) as well as for second crop (7.3% and 6.7% respectively at first and second harvests).

Oxalate content decreased significantly with increase in the phosphorus levels. All the three levels of phosphorus recorded significantly lower oxalate content than the control for both the crops. The lowest oxalate content was recorded under the P_3 level (5.65% at first harvest and 5.16% at second harvest in the case of first crop). In the case of second crop the oxalate content recorded was 6.16 per cent at first harvest and 5.71 per cent at second harvest. The P_2 level significantly recorded high level oxalate content which were 5.81 per cent and 5.32 per cent at first and second harvests respectively for first crop as compared to P_3. In the second crop, the values were 6.31 per cent and 5.83 per cent respectively for first and second harvests. The P_1 level recorded higher oxalate content than P_2 (5.99% at first harvest and 5.44% at second harvest of first crop). In the second crop the oxalate contents were 6.5 per cent and 5.96 per cent respectively at first and second harvests.

The oxalate content was found to increase significantly with increase in the potassium levels, but recorded a significantly lower oxalate content than the control for both the crops. The K_1 level recorded the lowest oxalate content of 5.71 per cent and 5.21 per cent at first and second harvests respectively for the first crop. For second crop the values were 6.21 per cent and 5.75 per cent respectively for first and second harvests. The effect of K_1 was followed by K_2 for first crop (5.81% at first harvest and 5.3% at second harvest) and second crop (6.31% at first harvest and 5.87% at second harvest). The K_3 level effected a significantly higher oxalate content for the first crop (5.94% at first harvest and 5.4% at second harvest) and for the second crop these values were 6.45 per cent and 5.95 per cent at first and second harvests respectively.

4.3.1.2.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops (Table 14a). The N_3P_3 combination recorded the lowest oxalate content of 5.19 per cent at first harvest and 4.72 per cent at second harvest of the first crop. For the second crop the corresponding values were 5.71 per cent and 5.27 per cent respectively. The N_1P_1 combination recorded the highest oxalate content for first crop (6.44% and 5.88% at first and second harvests respectively) and for second crop (6.93% and 6.41% respectively at first and second harvests).

For both the crops, nitrogen and potassium interactions were significant (Table 14b). The N_3K_1 combination recorded minimum oxalate content (5.24% at first harvest and 4.74% at second harvest) for first crop and 5.76% and 5.26% respectively at first and second harvests for second crop. The highest oxalate content was recorded by N_1K_3 for the first crop (6.40% and 5.87% at first and second harvests respectively) and for the second crop (6.91% and 6.43% respectively at first and second harvests).

Phosphorus and potassium interactions were also found to be significant (Table 14c). The lowest oxalate content of 5.52 per cent (first harvest) and 5.07 per cent (second harvest) were recorded under P_3K_1 in the first crop. For the second crop the values were 6.03 per cent and 5.6 per cent at first and second harvests respectively. The P_1K_3 combination recorded the highest oxalate content of 6.1 per cent and 5.55 per cent at first and second harvests respectively for first crop. In the second crop, the oxalate content were 6.66 per cent and 6.09 per cent respectively for first and second harvests.

4.3.2 Nitrate content

4.3.2.1 Nitrate content of plants with one vegetable harvest

4.3.2.1.1 Main effects of NPK

The data on the main effects are presented in Table 15 and the analysis of variance in Appendix X.

Nitrogen had highly significant effect on the nitrate content of the crop. Nitrate content increased significantly with the increase in nitrogen levels. The N_1 level of nitrogen recorded a nitrate content of 0.39 per cent for first crop and 0.46 per cent for second crop. This was significantly lower than N_2 level (0.52% and 0.58% for the first and second crops respectively). The highest nitrate content of 0.65 per cent for the first crop and 0.74 per cent for second crop were recorded under N_3 level. The controls recorded the lowest nitrate content of 0.20 per cent for first crop and 0.25 per cent for second crop which was significantly different from the three nitrogen levels.

The effect of phosphorus on nitrate content was in significant (0.522%, 0.523% and 0.518% at P_1, P_2 and P_3 levels respectively) for the first crop. For the second crop these values were 0.596 per cent, 0.597 per cent and 0.593 per cent respectively at P_1, P_2 and P_3 levels.

Table 15. Effect of nitrogen, phosphorus and potassium on nitrate content (%)

	Nitrate content of plants with one vegetable harvest		Nitrate content of plants with two vegetable harvests			
			First crop		Second crop	
	First crop	Second crop	First harvest	Second harvest	First harvest	Second harvest
Levels of N (kg ha^{-1})						
50	0.39	0.46	0.40	0.32	0.47	0.39
100	0.52	0.58	0.51	0.46	0.59	0.52
150	0.65	0.74	0.65	0.58	0.73	0.65
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0033	0.0027	0.00217	0.00164	0.002388	0.00175
CD(0.05)	0.009	0.0077	0.0063	0.00475	0.006931	0.00509
Levels of P_2O_5 (kg ha^{-1})						
50	0.522	0.596	0.522	0.453	0.596	0.519
75	0.523	0.597	0.521	0.454	0.598	0.517
100	0.518	0.593	0.519	0.453	0.593	0.518
`F' test	NS	NS	NS	NS	NS	NS
SEm±	0.0033	0.0027	0.00217	0.00164	0.002388	0.00175
CD(0.05)	-	-	-	-	-	-
Levels of K_2O (kg ha^{-1})						
50	0.456	0.529	0.459	0.394	0.531	0.459
75	0.519	0.592	0.515	0.451	0.593	0.518
100	0.589	0.666	0.588	0.514	0.664	0.577
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0033	0.0027	0.00217	0.00164	0.002388	0.00175
CD(0.05)	0.009	0.0077	0.0063	0.00475	0.006931	0.00509

Nitrate content was found to increase significantly with increase in the potassium levels. All the three levels of potassium recorded significantly higher nitrate content than the control for both the crops. The minimum nitrate content of 0.456 per cent for the first crop and 0.529 per cent for the second crop were observed under K_1 level. This was significantly superior to K_2 (0.519% for first crop and 0.592% for second crop). The K_3 level recorded the highest nitrate content of 0.589 per cent and 0.666 per cent for the first and second crops respectively.

4.3.2.1.2 Interaction effects of NPK

Nitrogen and potassium interaction alone was significant. Among the treatment combinations, N_1K_1 recorded the minimum nitrate content of 0.33 per cent and 0.4 per cent respectively for first and second crops (Table 16b). The highest nitrate content of 0.73 per cent for first crop and 0.81 per cent for second crop were recorded under N_3K_3.

Nitrogen and phosphorus interaction was found to be insignificant (Table 16a). The interaction effect of phosphorus and potassium on nitrate content was also insignificant (Table 16c).

4.3.2.2 Nitrate content of plants with two vegetable harvests

4.3.2.2.1 Main effects of NPK

There was a highly significant increase in nitrate content with increase in nitrogen levels. For the first crop, the controls recorded the lowest values of nitrate content (0.19% at first harvest and 0.17% at second harvest). The same trend was observed with second crop also (0.25% at first harvest and 0.24% at second harvest).

The control was significantly different from N_1 level (0.40% at first harvest and 0.32% at second harvest) for the first crop and for the second crop (0.47% at first harvest and 0.39% at second harvest). The effect of N_2 level was higher than N_1 level which effected a value of 0.51 per cent and 0.46 per cent at first and second harvests respectively for first crop and 0.59 per cent and 0.52 per cent respectively at first and second harvests in second crop. The highest nitrate content of 0.65 per cent and 0.58 per cent at first and second harvests of first crop were recorded under N_3 level. In the second crop also the same trend was followed (0.73% and 0.65% at first and second harvests respectively).

There was no significant effect of phosphorus on nitrate content for both the crops (0.522%, 0.521% and 0.519% respectively at P_1, P_2 and P_3 levels of first crop at first harvest and at second harvest it was 0.453 per cent, 0.454 per cent and 0.453 per cent respectively). For the second crop the values of P_1, P_2 and P_3 levels were 0.596 per cent, 0.598 per cent and 0.593 per cent respectively at first harvest and 0.519 per cent, 0.517 per cent and 0.518 per cent respectively at second harvest.

All the three levels of potassium recorded significantly higher nitrate content than the control for both the crops. The lowest nitrate content was recorded under K_1 level for the first crop (0.459% at first harvest and 0.394% at second harvest) and for the second crop with the same trend (0.531% at first harvest and 0.459% at second harvest). The effect of K_2 level was significantly higher than K_1 level which recorded a value of 0.515 per cent and 0.451 per cent at first and second harvests respectively for the first crop. The same trend was followed in the second crop with values of 0.593 per cent and 0.518 per cent respectively for first and second harvests. The highest nitrate content was recorded under K_3 level for the first crop

Table 16a. Effect of N x P interaction on the nitrate content (%)

Levels of N (kg ha^{-1})	Plants with one vegetable harvest (30 DAP)				Plants with two vegetable harvests							
	Levels of P_2O_5 (kg ha^{-1})				First harvest (30 DAP) Levels of P_2O_5 (kg ha^{-1})				Second harvest (50 DAP) Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	0.40	0.40	0.39	0.39	0.40	0.39	0.40	0.40	0.32	0.32	0.32	0.32
100	0.52	0.52	0.52	0.52	0.52	0.52	0.51	0.51	0.45	0.46	0.46	0.46
150	0.65	0.66	0.65	0.65	0.65	0.65	0.65	0.65	0.59	0.58	0.59	0.58
Mean	0.522	0.523	0.518		0.522	0.521	0.519		0.453	0.454	0.453	
SEm±	0.0057				0.0038				0.0028			
CD(0.05)	-				-				-			
Second crop												
50	0.47	0.47	0.46	0.46	0.47	0.48	0.47	0.47	0.39	0.39	0.39	0.39
100	0.59	0.59	0.58	0.58	0.60	0.59	0.58	0.59	0.52	0.52	0.52	0.52
150	0.73	0.74	0.74	0.74	0.72	0.73	0.73	0.73	0.65	0.64	0.65	0.65
Mean	0.596	0.597	0.593		0.596	0.598	0.593		0.519	0.517	0.518	
SEm±	0.004624				0.00414				0.00304			
CD(0.05)	-				-				-			

Table 16b. Effect of N x K interaction on the nitrate content (%)

Levels of N (kg ha^{-1})	Plants with one vegetable harvest (30 DAP)				Plants with two vegetable harvests							
					First harvest (30 DAP)				Second harvest (50 DAP)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg.ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	0.33	0.39	0.46	0.39	0.34	0.39	0.47	0.40	0.26	0.31	0.38	0.32
100	0.45	0.51	0.58	0.52	0.45	0.51	0.58	0.51	0.40	0.46	0.51	0.46
150	0.59	0.65	0.73	0.65	0.59	0.65	0.72	0.65	0.52	0.58	0.65	0.58
Mean	0.456	0.519	0.589		0.459	0.515	0.588		0.394	0.451	0.514	
SEm±	0.0057				0.00377				0.002833			
CD(0.05)	0.0166				0.0109				0.00822			
Second crop												
50	0.40	0.46	0.53	0.46	0.40	0.47	0.54	0.47	0.33	0.38	0.45	0.39
100	0.52	0.58	0.65	0.58	0.53	0.58	0.65	0.59	0.47	0.52	0.57	0.52
150	0.67	0.73	0.81	0.74	0.66	0.73	0.80	0.73	0.59	0.65	0.71	0.65
Mean	0.529	0.592	0.666		0.531	0.593	0.664		0.459	0.518	0.577	
SEm±	0.004624				0.00414				0.00304			
CD(0.05)	0.0134				0.012				0.0088			

Table 16c. Effect of P x K interaction on the nitrate content (%)

Levels of P_2O_5 (kg ha^{-1})	Plants with one vegetable harvest (30 DAP) Levels of K_2O (kg ha^{-1})				Plants with two vegetable harvests: First harvest (30 DAP) Levels of K_2O (kg ha^{-1})				Plants with two vegetable harvests: Second harvest (50 DAP) Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	0.458	0.52	0.587	0.522	0.465	0.515	0.585	0.522	0.392	0.452	0.515	0.453
75	0.455	0.52	0.59	0.523	0.460	0.515	0.588	0.521	0.398	0.450	0.513	0.454
100	0.453	0.51	0.59	0.518	0.453	0.515	0.590	0.519	0.393	0.452	0.513	0.453
Mean	0.456	0.519	0.589		0.459	0.515	0.588		0.394	0.451	0.514	
SEm±	0.0057				0.00377				0.002833			
CD(0.05)	-				-				-			
Second crop												
50	0.538	0.592	0.658	0.596	0.53	0.60	0.66	0.596	0.46	0.52	0.58	0.519
75	0.527	0.595	0.670	0.597	0.53	0.60	0.67	0.598	0.46	0.52	0.57	0.517
100	0.522	0.588	0.668	0.593	0.53	0.59	0.66	0.593	0.46	0.52	0.58	0.518
Mean	0.529	0.592	0.666		0.531	0.593	0.664		0.459	0.518	0.577	
SEm±	0.004624				0.00414				0.00304			
CD(0.05)	-				-				-			

(0.588% and 0.514% at first and second harvests respectively) and also for the second crop (0.664% at first harvest and 0.577% at second harvest).

4.3.2.2.2 Interaction effects of NPK

Nitrogen and potassium interaction alone was found to be significant. Among the treatment combinations N_1K_1 recorded the minimum nitrate content of 0.34 per cent at first harvest and 0.26 per cent at second harvest of the first crop. In the second crop, these values were 0.40 and 0.33 per cent at first and second harvests respectively. The N_3K_3 combination recorded the highest nitrate content for first crop (0.72% and 0.65% at first and second harvests respectively) and also for the second crop (0.8% and 0.71% respectively at first and second harvests).

Nitrogen and phosphorus interaction was found to be insignificant. The interaction effect of phosphorus and potassium on nitrate content was also insignificant.

4.4 Seed yield

4.4.1 Seed yield of plants with no vegetable harvest

4.4.1.1 Main effects of NPK

The data on the main effects and the analysis of variance are presented in Table 17 and in Appendix XI respectively.

A highly significant increase in seed yield was recorded with increase in nitrogen level. The N_3 level of nitrogen recorded the highest seed yield of 6.49 g/plant, 205.33 g/plot and 1303.68 kg ha^{-1} for the first crop and it was 7.28 g/plant, 231.11 g/plot and 1467.4 kg ha^{-1} for the second crop. The N_3 level effected significantly higher seed yield than that of N_2 level (4.52 g/plant, 134.94 g/plot and 856.79 kg ha^{-1}) for the first crop and in the second crop the values were 4.93 g/plant, 167.83 g/plot and 1065.6 kg ha^{-1}. The N_2 level significantly resulted in higher seed yield than N_1 level which recorded 2.44 g/plant, 87.58 g/plot and 556.08 kg ha^{-1} for the first crop and 3.11 g/plant, 108.53 g/plot and 689.07 kg ha^{-1} for the second crop. All the three nitrogen levels were highly significant to bring about higher seed yield than the control which recorded an yield of 0.78 g/plant, 39.83 g/plot and 252.91 kg ha^{-1} for the first crop. In the second crop the seed yields were 1.25 g/plant, 44.8 g/plot and 284.66 kg ha^{-1}

All the three levels of phosphorus recorded higher seed yield than the control for both the crops. The highest seed yield was recorded by P_3 level for the first crop (4.79 g/plant, 151.52 g/plot and 962.08 kg ha^{-1}) and for the second crop (5.43 g/plant, 178.25 g/plot and 1131.7 kg ha^{-1}). The P_3 level effected a significantly higher seed yield than P_2 level (4.49 g/plant, 143.22 g/plot and 909.35 kg ha^{-1} for the first crop and for the second crop 5.09 g/plant, 168.94 g/plot and 1072.7 kg ha^{-1}). The effect of P_2 level was followed by P_1 level which recorded a seed yield of 4.17 g/plant, 133.11 g/plot and 845.15 kg ha^{-1} for the first crop and 4.8 g/plant, 160.28 g/plot and 1017.6 kg ha^{-1} for the second crop.

The potassium levels also recorded higher seed yield than the control for both crops. The K_3 level recorded the highest seed yield of 4.82 g/plant, 150.69 g/plot and 956.79 kg ha^{-1} in the first crop. In the second crop it was 5.39 g/plant, 178.06 g/plot and 1130.5 kg ha^{-1}. This was followed by K_2 which recorded a seed yield of 4.46 g/plant, 142.89 g/plot and 907.23 kg ha^{-1} for first crop. Similar was the trend with second crop also (5.08 g/plant, 168.56 g/plot and 1070.2 kg ha^{-1}). The

Table 17. Effect of NPK on the seed yield of plants with no vegetable harvest

	Weight of seeds					
	First crop			Second crop		
	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Levels of N (kg ha^{-1})						
50	2.44	87.58	556.08	3.11	108.53	689.07
100	4.52	134.94	856.79	4.93	167.83	1065.60
150	6.49	205.33	1303.68	7.28	231.11	1467.40
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.054	1.375	8.729	0.0533	2.058	13.0695
CD(0.05)	0.157	3.99	25.33	0.155	5.973	37.927
Levels of P_2O_5 (kg ha^{-1})						
50	4.17	133.11	845.15	4.80	160.28	1017.60
75	4.49	143.22	909.35	5.09	168.94	1072.70
100	4.79	151.52	962.08	5.43	178.25	1131.70
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.054	1.375	8.729	0.0533	2.058	13.0695
CD(0.05)	0.157	3.99	25.33	0.155	5.973	37.927
Levels of K_2O (kg ha^{-1})						
50	4.17	134.28	852.56	4.85	160.86	1021.30
75	4.46	142.89	907.23	5.08	168.56	1070.20
100	4.82	150.69	956.79	5.39	178.06	1130.50
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.054	1.375	8.729	0.0533	2.058	13.0695
CD(0.05)	0.157	3.99	25.33	0.155	5.973	37.927

effect of K_2 level was more than K_1 level for the first crop (4.17 g/plant, 134.28 g/plot and 852.56 kg ha^{-1}) and also for the second crop (4.85 g/plant, 160.86 g/plot and 1021.3 kg ha^{-1}).

4.4.1.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for seed yield in both the crops (Table 18a). The N_3P_3 combination recorded the highest seed yield of 6.85 g/plant, 217.5 g/plot and 1380.95 kg ha^{-1} in the first crop. For the second crop these values were 7.63 g/plant, 242.25 g/plot and 1538.1 kg ha^{-1}. The N_1P_1 combination gave the minimum seed yield 2.3 g/plant, 82.67 g/plot and 524.87 kg ha^{-1} for the first crop while for the second crop the values were 2.93 g/plant, 102.17 g/plot and 648.7 kg ha^{-1}.

For both the crops, nitrogen and potassium interactions were significant on seed yield (Table 18b). The highest seed yield was recorded by N_3K_3 for the first crop (6.87 g/plant, 215.83 g/plot and 1370.4 kg ha^{-1}) and in the second crop (7.53 g/plant, 240.92 g/plot and 1529.6 kg ha^{-1}). The lowest seed yield was recorded by N_1K_1 for the first crop (2.13 g/plant, 83.33 g/plot and 529.1 kg ha^{-1}) and for the second crop (2.85 g/plant, 100.5 g/plot and 638.1 kg ha^{-1}).

Phosphorus and potassium interactions were also found to be significant (Table 18c). The highest seed yield was recorded by P_3K_3 for first crop (5.15 g/plant, 159.42 g/plot and 1012.17 kg ha^{-1}) and also for the second crop (5.72 g/plant, 188 g/plot and 1193.7 kg ha^{-1}). The P_1K_1 combination recorded the lowest seed yield of 4.02 g/plant, 127.33 g/plot and 808.5 kg ha^{-1} for the first crop and 4.63 g/plant, 155.33 g/plot and 986.2 kg ha^{-1} for the second crop.

Table 18a. Effect of N x P interaction on the seed yield of plants with no vegetable harvest

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	2.3	2.43	2.6	2.44	82.67	87.83	92.25	87.58	524.87	557.67	585.71	556.08
100	3.98	4.63	4.93	4.52	121.67	138.33	144.83	134.94	772.49	878.31	919.58	856.79
150	6.23	6.4	6.85	6.49	195.0	203.5	217.5	205.33	1238.1	1292.1	1380.95	1303.68
Mean	4.17	4.49	4.79		133.11	143.22	151.52		845.15	909.35	962.08	
SEm±	0.0935				2.381				15.119			
CD(0.05)	0.2712				6.909				43.873			
Second crop												
50	2.93	3.08	3.32	3.11	102.17	108.25	115.17	108.53	648.7	687.3	731.2	689.07
100	4.50	4.95	5.35	4.93	157.25	168.92	177.33	167.83	998.4	1072.5	1125.9	1065.6
150	6.97	7.23	7.63	7.28	221.42	229.67	242.25	231.11	1405.8	1458.2	1538.1	1467.4
Mean	4.8	5.09	5.43		160.28	168.94	178.25		1017.6	1072.7	1131.7	
SEm±	0.0924				3.565				22.637			
CD(0.05)	0.268				10.345				65.691			

Table 18b. Effect of N x K interaction on the seed yield of plants with no vegetable harvest

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	2.13	2.4	2.8	2.44	83.33	87.83	91.58	87.58	529.1	557.67	581.48	556.08
100	4.22	4.53	4.8	4.52	124.17	136.0	144.67	134.94	788.4	863.5	918.5	856.79
150	6.17	6.45	6.87	6.49	195.33	204.83	215.83	205.33	1240.2	1300.5	1370.4	1303.68
Mean	4.17	4.46	4.82		134.28	142.89	150.69		852.56	907.23	956.79	
SEm±	0.0935				2.381				15.119			
CD(0.05)	0.2712				6.909				43.873			
Second crop												
50	2.85	3.08	3.4	3.11	100.5	108.67	116.42	108.53	638.1	689.95	739.15	689.07
100	4.62	4.93	5.25	4.93	158.75	167.92	176.83	167.83	1007.9	1066.1	1122.75	1065.6
150	7.08	7.22	7.53	7.28	223.33	229.08	240.92	231.11	1418.0	1454.5	1529.6	1467.4
Mean	4.85	5.08	5.39		160.86	168.56	178.06		1021.3	1070.2	1130.5	
SEm±	0.0924				3.565				22.637			
CD(0.05)	0.268				10.345				65.691			

Table 18c. Effect of P x K interaction on the seed yield of plants with no vegetable harvest

Levels of P_2O_5 (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	4.02	4.12	4.38	4.17	127.33	132.0	140.0	133.11	808.5	838.1	888.89	845.15
75	4.07	4.47	4.93	4.49	132.83	144.17	152.67	143.22	843.39	915.34	969.31	909.35
100	4.43	4.8	5.15	4.79	142.67	152.5	159.42	151.52	905.8	968.25	1012.17	962.08
Mean	4.17	4.46	4.82		134.28	142.89	150.69		852.56	907.23	956.79	
SEm±	0.0935				2.381				15.119			
CD(0.05)	0.2712				6.909				43.873			
Second season												
50	4.63	4.68	5.08	4.8	155.33	156.83	168.67	160.28	986.2	995.78	1070.9	1017.6
75	4.77	5.12	5.38	5.09	159.17	170.17	177.5	168.94	1010.6	1080.4	1126.98	1072.7
100	5.15	5.43	5.72	5.43	168.08	178.67	188.0	178.25	1067.2	1134.4	1193.7	1131.7
Mean	4.85	5.08	5.39		160.86	168.56	178.06		1021.3	1070.2	1130.5	
SEm±	0.0924				3.565				22.637			
CD(0.05)	0.268				10.345				65.691			

4.4.2 Seed yield of plants with one vegetable harvest

4.4.2.1 Main effects of NPK

The data on the main effects and the analysis of variance are presented in Table 19 and in Appendix XII respectively.

In both the crops, there was a highly significant increase in seed yield with increase in nitrogen level. The N_3 level of nitrogen recorded the highest seed yield for the first crop (6.01 g/plant, 200 g/plot and1269.8 kg ha^{-1}). In the second crop the seed yield was 6.45 g/plant, 222 g/plot and 1414.6 kg ha^{-1}. The N_3 level was highly significant and superior to N_2 level of nitrogen which recorded a seed yield of 4.24 g/plant, 132.67 g/plot and 842.3 kg ha^{-1} for the first crop. It was 4.52 g/plant, 162.08 g/plot and 1029.1 kg ha^{-1} for the second crop. The N_2 level of nitrogen was highly significant and superior to N_1 level. The values of N_1 were 2.23 g/plant, 85.56 g/plot and 543.2 kg ha^{-1} for the first crop and for the second crop the values were 2.46 g/plant, 104.64 g/plot and 664.37 kg ha^{-1}. All the three nitrogen levels were highly significant and superior to the control for seed yield. The control recorded a seed yield of 0.7 g/plant, 33.83 g/plot and 214.8 kg ha^{-1} for the first crop and 1 g/plant, 43.67 g/plot and 277.25 kg ha^{-1} for the second crop.

The three levels of phosphorus recorded a higher seed yield than the control for both the crops. The highest seed yield was recorded by P_3 level in the first crop (4.51 g/plant, 147.97 g/plot and 939.5 kg ha^{-1}) and for the second crop (4.82 g/plant, 171 g/plot and 1085.7 kg ha^{-1}). This was followed by P_2 which recorded a seed yield of 4.14 g/plant, 139.03 g/plot and 882.7 kg ha^{-1} for the first crop. A similar trend was maintained in the second crop also (4.46 g/plant, 162.56 g/plot and

Table 19. Effect of NPK on the seed yield of plants with one vegetable harvest

	Weight of seeds					
	First crop			Second crop		
	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Levels of N (kg ha^{-1})						
50	2.23	85.56	543.20	2.46	104.64	664.37
100	4.24	132.67	842.30	4.52	162.08	1029.10
150	5.01	200.00	1269.80	6.45	222.00	1414.60
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0437	1.3367	8.488	0.0689	1.3798	8.762
CD(0.05)	0.1269	3.879	24.632	0.2	4.004	25.426
Levels of P_2O_5 (kg ha^{-1})						
50	3.82	131.22	833.2	4.16	155.97	990.30
75	4.14	139.03	882.70	4.46	162.56	1032.10
100	4.51	147.97	939.50	4.82	171.00	1085.70
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0437	1.3367	8.488	0.0689	1.3798	8.762
CD(0.05)	0.1269	3.879	24.632	0.2	4.004	25.426
Levels of K_2O (kg ha^{-1})						
50	3.93	132.42	840.70	4.20	156.00	990.50
75	4.11	139.25	884.10	4.46	163.17	1035.98
100	4.43	146.56	930.50	4.77	170.36	1081.66
`F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0437	1.3367	8.488	0.0689	1.3798	8.762
CD(0.05)	0.1269	3.879	24.632	0.2	4.004	25.426

1032.1 kg ha^{-1}). The P_2 level was superior to P_1 level which recorded a seed yield of 3.82 g/plant, 131.22 g/plot and 833.2 kg ha^{-1} for the first crop and in the second crop the values were 4.16 g/plant, 155.97 g/plot and 990.3 kg ha^{-1}.

The three levels of potassium also recorded a higher seed yield than the control for both the crops. The highest seed yield was recorded by K_3 level for the first crop (4.43 g/plant, 146.56 g/plot and 930.5 kg ha^{-1}) and for the second crop also (4.77 g/plant, 170.36 g/plot and 1081.66 kg ha^{-1}). The K_3 level was significantly superior to K_2 level which effected a seed yield of 4.11 g/plant, 139.25 g/plot and 884.1 kg ha^{-1} for first crop while it was 4.46 g/plant, 163.17 g/plot and 1035.98 kg ha^{-1} for the second crop. The effect of K_2 level was followed by K_1 level which recorded a seed yield of 3.93 g/plant, 132.42 g/plot and 840.7 kg ha^{-1} for the first crop. In the second crop these values were 4.2 g/plant, 156 g/plot and 990.5 kg ha^{-1}.

4.4.2.2 Interaction effects of NPK

The nitrogen and the phosphorus interactions were significant for both the crops (Table 20a). The highest seed yield was recorded by N_3P_3 for the first crop (6.37 g/plant, 212.33 g/plot and 1348.15 kg ha^{-1}). In the second crop the values were 6.87 g/plant, 230.33 g/plot and 1462.43 kg ha^{-1}. The lowest seed yield was recorded by N_1P_1 (1.83 g/plant, 79.5 g/plot and 504.76 kg ha^{-1} for the first crop while it was 2.18 g/plant, 97.92 g/plot and 621.69 kg ha^{-1} for the second crop).

Nitrogen and potassium interactions were significant for both the crops (Table 20b). The N_3K_3 combination recorded the highest seed yield of 6.35 g/plant, 208.5 g/plot and 1323.8 kg ha^{-1} in the first crop. For the second crop the yields were

Table 20a. Effect of N x P interaction on the seed yield of plants given one vegetable harvest

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	1.83	2.22	2.63	2.23	79.5	85.5	91.67	85.56	504.76	542.86	582.01	543.2
100	3.95	4.25	4.52	4.24	125.0	133.08	139.92	132.67	793.65	844.9	888.36	842.3
150	5.68	5.97	6.37	6.01	189.17	198.5	212.33	200.0	1201.06	1260.32	1348.15	1269.8
Mean	3.82	4.14	4.51		131.22	139.03	147.97		833.2	882.7	939.5	
SEm±	0.0757				2.3152				14.702			
CD(0.05)	0.2198				6.719				42.664			
Second crop												
50	2.18	2.45	2.75	2.46	97.92	103.0	113.0	104.64	621.69	653.97	717.46	664.4
100	4.17	4.55	4.83	4.52	154.75	161.83	169.67	162.08	982.54	1027.5	1077.25	1029.1
150	6.12	6.37	6.87	6.45	215.25	222.83	230.33	222.00	1366.67	1414.82	1462.43	1414.6
Mean	4.16	4.46	4.82		155.97	162.56	171.00		990.3	1032.1	1085.7	
SEm±	0.1194				2.3899				15.1759			
CD(0.05)	0.3464				6.935				44.039			

Table 20b. Effect of N x K interaction on the seed yield of plants given one vegetable harvest

Levels of N ($kg\ ha^{-1}$)	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	2.00	2.22	2.47	2.23	80.33	85.17	91.17	85.56	540.74	578.84	543.21	543.2
100	4.05	4.20	4.47	4.24	125.58	132.42	140.0	132.67	797.35	840.74	888.89	842.3
150	5.75	5.92	6.35	6.01	191.33	200.17	208.5	200.00	1214.8	1270.9	1323.8	1269.8
Mean	3.93	4.11	4.43		132.42	139.25	146.56		840.7	884.1	930.5	
SEm±	0.0757				2.3152				14.702			
CD(0.050	0.2198				6.719				42.664			
Second crop												
50	2.20	2.43	2.75	2.46	97.33	104.67	111.92	104.64	617.99	664.55	710.58	664.4
100	4.25	4.53	4.77	4.52	154.75	161.67	169.83	162.08	982.54	1026.46	1078.31	1029.1
150	6.15	6.42	6.78	6.45	215.92	223.17	229.33	222.0	1370.9	1416.9	1456.1	1414.6
Mean	4.2	4.46	4.77		156.0	163.17	170.36		990.5	1035.98	1081.66	
SEm±	0.1194				2.3899				15.1759			
CD(0.05)	0.3464				6.935				44.039			

Table 20c. Effect of P x K interaction on the seed yield of plants given one vegetable harvest

Levels of P_2O_5 (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	3.7	3.77	4.00	3.82	125.83	131.33	136.5	131.22	798.9	833.86	866.67	833.2
75	3.85	4.13	4.45	4.14	130.42	139.5	147.17	139.03	828.04	885.7	934.4	882.7
100	4.25	4.43	4.83	4.51	141.00	146.92	156.0	147.97	895.24	932.8	990.5	939.5
Mean	3.93	4.11	4.43		132.42	139.25	146.56		840.7	884.1	930.5	
SEm±	0.0757				2.3152				14.702			
CD(0.05)	0.2198				6.719				42.664			
Second crop												
50	4.02	4.08	4.37	4.16	150.67	155.33	161.92	155.97	956.6	986.2	1028.04	990.3
75	4.1	4.53	4.73	4.46	155.0	162.33	170.33	162.56	984.13	1030.69	1081.48	1032.1
100	4.48	4.77	5.2	48.2	162.33	171.83	178.83	171.0	1030.69	1091.0	1135.45	1085.7
Mean	4.2	4.46	4.77		156.0	163.17	170.36		990.5	1035.98	1081.66	
SEm±	0.1194				2.3899				15.1759			
CD(0.05)	0.3464				6.935				44.039			

6.78 g/plant, 229.33 g/plot and 1456.1 kg ha^{-1}. The N_1K_1 combination gave the minimum seed yield of 2.0 g/plant, 80.33 g/plot and 540.74 kg ha^{-1} for the first crop and for the second crop the values were 2.2 g/plant, 97.33 g/plot and 617.99 kg ha^{-1}.

The phosphorus and the potassium interactions were also significant (Table 20c). The highest seed yield was recorded by P_3K_3 for first crop (4.83 g/plant, 156 g/plot and 990.5 kg ha^{-1}) and for second crop (5.2 g/plant, 178.83 g/plot and 1135.45 kg ha^{-1}). The minimum seed yield was recorded by P_1K_1 for first crop (3.7 g/plant, 125.83 g/plot and 798.9 kg ha^{-1}). For the second crop the values were 4.02 g/plant, 150.67 g/plot and 956.6 kg ha^{-1}.

4.4.3 Seed yield of plants with two vegetable harvests

4.4.3.1 Main effects of NPK

The data on the main effects and the analysis of variance are presented in Table 21 and in Appendix XIII respectively.

There was a highly significant increase in seed yield with increase in nitrogen level. The N_3 level of nitrogen recorded the highest seed yield of 3.11 g/plant, 66.78 g/plot and 423.99 kg ha^{-1} for the first crop and it was 3.64 g/plant, 77.22 g/plot and 490.3 kg ha^{-1} for the second crop. The N_3 level was highly significant and superior to N_2 level (1.98 g/plant, 46.33 g/plot and 294.18 kg ha^{-1}) for the first crop. In the case of second crop the yields were 2.45 g/plant, 56.25 g/plot and 357.14 kg ha^{-1}. The N_2 level of nitrogen was highly significant and superior to N_1 level for seed yield with a value of 0.93 g/plant, 27.72 g/plot and 176 kg ha^{-1} for the first crop. In the second crop the seed yields were 1.33 g/plant, 36.08 g/plot and 229.1 kg ha^{-1}. All the three nitrogen levels were highly significant and

Table 21. Effect of NPK on the seed yield of plants given two vegetable harvests

	Weight of seeds					
	First crop			Second crop		
	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Levels of N (kg ha^{-1})						
50	0.93	27.72	176.01	1.33	36.08	229.10
100	1.98	46.33	294.18	2.45	56.25	357.14
150	3.11	66.78	423.99	3.64	77.22	490.30
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0345	0.56	3.556	0.0303	0.4963	3.1512
CD(0.05)	0.1002	1.625	10.319	0.0878	1.44	9.145
Levels of P_2O_5 (kg ha^{-1})						
50	1.87	44.67	283.60	2.38	53.42	339.15
75	2.02	46.75	296.83	2.47	56.86	361.02
100	2.12	49.42	313.80	2.56	59.28	376.37
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0345	0.56	3.556	0.0303	0.4963	3.1512
CD(0.05)	0.1002	1.625	10.3189	0.0878	1.44	9.145
Levels of K_2O (kg ha^{-1})						
50	1.87	44.89	285.00	2.31	54.25	344.40
75	1.99	46.78	297.00	2.46	56.42	358.20
100	2.15	49.17	312.17	2.66	58.89	373.90
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.0345	0.56	3.556	0.0303	0.4963	3.1512
CD(0.05)	0.1002	1.625	10.319	0.0878	1.44	9.145

superior to control (0.5 g/plant, 13.8 g/plot and87.83 kg ha^{-1}) for the first crop and 1.07 g/plant, 16.83 g/plot and 106.88 kg ha^{-1} for the second crop.

The phosphorus levels also recorded higher seed yield than the control for both the crops. The P_3 level recorded the highest seed yield of 2.12 g/plant, 49.42 g/plot and 313.8 kg ha^{-1} in the first crop. In the second crop it was 2.56 g/plant, 59.28 g/plot and 376.37 kg ha^{-1}. This was followed by P_2 which recorded seed yield of 2.02 g/plant, 46.75 g/plot and 296.83 kg ha^{-1} for the first crop while it was 2.47 g/plant, 56.86 g/plot and 361.02 kg ha^{-1} for the second crop. The effect of P_2 level was followed by P_1 level which recorded a seed yield of 1.87 g/plant, 44.67 g/plot and 283.6 kg ha^{-1} for the first crop. In the second crop the seed yields were 2.38 g/plant, 53.42 g/plot and 339.15 kg ha^{-1}.

The three levels of potassium recorded higher seed yield than the control for both the crops. The highest seed yield was recorded by K_3 level for the first crop (2.15 g/plant, 49.17 g/plot and 312.17 kg ha^{-1}) and also for the second crop (2.66 g/plant, 58.89 g/plot and 373.9 kg ha^{-1}). The K_3 level was significantly superior to K_2 level which recorded seed yield of 1.99 g/plant, 46.78 g/plot and 297 kg ha^{-1} for the first crop. Similar trend was observed in second crop also (2.46 g/plant, 56.42 g/plot and 358.2 kg ha^{-1}). The K_2 level was superior to K_1 (1.87 g/plant, 44.89 g/plot and 285 kg ha^{-1}) for the first crop and for the second crop (2.31 g/plant, 54.25 g/plot and 344.4 kg ha^{-1}).

4.4.3.2 Interaction effects of NPK

The nitrogen and the phosphorus interactions were significant for both the crops (Table 22a). The N_3P_3 combination recorded the highest seed yield of

Table 22a. Effect of N x P interaction on the seed yield of plants given two vegetable harvests

Levels of N (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	0.85	0.95	0.98	0.93	26.17	27.33	29.67	27.72	166.14	173.55	188.36	176.01
100	1.83	2.00	2.10	1.98	43.33	46.67	49.00	46.33	275.13	296.30	303.10	294.18
150	2.93	3.10	3.28	3.11	64.50	66.25	69.58	66.78	409.50	420.60	441.80	423.99
Mean	1.87	2.02	2.12		44.67	46.75	49.42		283.60	296.83	313.80	
SEm±	0.0598				0.970				6.1588			
CD(0.05)	0.1736				2.815				17.873			
Second crop												
50	1.27	1.37	1.35	1.33	33.75	36.08	38.42	36.08	214.29	229.10	243.92	229.10
100	2.38	2.45	2.52	2.45	52.33	56.92	59.5	56.25	332.28	361.38	377.78	357.14
150	3.50	3.60	3.82	3.64	74.17	77.58	79.92	77.22	470.9	492.6	507.4	490.3
Mean	2.38	2.47	2.56		53.42	56.86	59.28		339.15	361.02	376.37	
SEM±	0.0524				0.8597				5.4581			
CD(0.05)	0.1521				2.495				15.839			

Table 22b. Effect of N x K interaction on the seed yield of plants given two vegetable harvests

Levels of N ($kg\ ha^{-1}$)	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)				Levels of K_2O ($kg\ ha^{-1}$)			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	0.88	0.87	1.03	0.93	25.83	27.67	29.67	27.72	164.02	175.66	188.36	176.01
100	1.82	2.00	2.12	1.98	44.17	46.33	48.50	46.33	280.42	294.18	307.94	294.18
150	2.90	3.10	3.32	3.11	64.67	66.33	69.33	66.78	410.58	421.16	440.12	423.99
Mean	1.87	1.99	2.15		44.89	46.78	49.17		285.00	297.00	312.17	
SEm±	0.0598				0.970				6.1588			
CD(0.05)	0.1736				2.815				17.873			
Second crop												
50	1.20	1.28	1.50	1.33	34.42	36.00	37.83	36.08	218.52	228.57	240.2	229.1
100	2.30	2.45	2.60	2.45	54.08	56.00	58.67	56.25	343.39	355.56	372.49	357.14
150	3.42	3.63	3.87	3.64	74.25	77.25	80.17	77.22	471.43	490.48	509.00	490.3
Mean	2.31	2.46	2.66		54.25	56.42	58.89		344.4	358.2	373.9	
SEm±	0.0524				0.8597				5.4581			
CD(0.05)	0.1521				2.495				15.839			

Table 22c. Effect of P x K interaction on the seed yield of plants given two vegetable harvests

Levels of P_2O_5 (kg ha^{-1})	Yield/plant (g)				Yield/plot (g)				Yield/ha (kg)			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	1.73	1.87	2.02	1.87	43.17	44.17	46.67	44.67	274.07	280.42	296.3	283.6
75	1.87	2.00	2.18	2.02	44.33	46.75	49.17	46.75	281.48	296.83	312.17	296.83
100	2.00	2.10	2.27	2.12	47.17	49.42	51.67	49.42	299.47	313.76	328.04	313.8
Mean	1.87	1.99	2.15		44.89	46.78	49.17		285.00	297.00	312.17	
SEm±	0.0598				0.970				6.1588			
CD(0.05)	0.1736				2.815				17.873			
Second crop												
50	2.25	2.35	2.55	2.38	51.83	53.00	55.42	53.42	329.10	336.51	351.85	339.15
100	2.30	2.52	2.60	2.47	54.17	57.00	59.42	56.86	343.92	361.90	377.20	361.02
150	2.37	2.50	2.82	2.56	56.75	59.25	61.83	59.28	360.3	376.2	392.6	376.37
Mean	2.31	2.46	2.66		54.24	56.42	58.89		344.4	358.2	373.9	
SEm±	0.0524				0.8597				5.4581			
CD(0.05)	0.1521				2.495				15.839			

3.28 g/plant, 69.58 g/plot and 441.8 kg ha^{-1} for the first crop. In the second crop the values were 3.82 g/plant, 79.92 g/plot and 507.4 kg ha^{-1}. The N_1P_1 combination gave minimum seed yield of 0.85 g/plant, 26.17 g/plot and 166.14 kg ha^{-1} for first crop while for the second crop the yields were 1.27 g/plant, 33.75 g/plot and 214.29 kg ha^{-1}.

For both the crops, nitrogen and potassium interactions were significant (Table 22b). The highest seed yield was recorded by N_3K_3 for first crop (3.32 g/plant, 69.33 g/plot and 440.21 kg ha^{-1}). In the second crop the seed yield values were 3.87 g/plant, 80.17 g/plot and 509 kg ha^{-1}. The lowest seed yield was recorded by N_1K_1 for the first crop (0.88 g/plant, 25.83 g/plot and 164.02 kg ha^{-1}) and also for the second crop (1.2 g/plant, 34.42 g/plot and 218.52 kg ha^{-1}).

Phosphorus and potassium interactions were also found to be significant (Table 22c). The highest seed yield was recorded by P_3K_3 for the first crop (2.27 g/plant, 51.67 g/plot and 328.04 kg ha^{-1}). Here P_3K_3 was found to be on par with P_3K_2 and P_2K_3 for the second crop the seed yields were 2.82 g/plant, 61.82 g/plot and 392.6 kg ha^{-1}. The P_1K_1 combination recorded the lowest seed yield of 1.73 g/plant, 43.17 g/plot and 274.07 kg ha^{-1} for the first crop and for the second crop (2.25 g/plant, 51.83 g/plot and 329.1 kg ha^{-1}).

A comparison of the effects of cuttings on the seed yield were also done. The analysis of variance is presented in Appendix XIV. The significance was tested using DMRT and the results of comparison are as follows.

Among the C_0 (no vegetable harvest), C_1 (one vegetable harvest) and C_2 (two vegetable harvests) treatments, C_0 recorded the highest seed yield of

4.486 g/plant, 142.6 g/plot and 905.309 kg ha^{-1} for the first crop (Table 23). For the second crop it was 5.106 g/plant, 169 g/plot and 1073 kg ha^{-1}. This was significantly superior to C_1 which recorded 4.158 g/plant, 139.4 g/plot and 885.1 kg ha^{-1} for the first crop and 4.476 g/plant, 163.2 g/plot and 1036.2 kg ha^{-1} for the second crop. The effect of C_1 was followed by C_2 (2.004 g/plant, 46.94 g/plot and 298 kg ha^{-1} for the first crop and 2.472 g/plant, 56.52 g/plot and 358.8 kg ha^{-1} for the second crop).

The interaction effect of nitrogen and cutting was found to be significant (Table 24a). The N_3C_0 combination recorded the highest seed yield of 6.494 g/plant, 205.3 g/plot and 1303.4 kg ha^{-1} in the first crop. Similar trend was maintained in the second crop also (7.278 g/plant, 231.1 g/plot and 1467.3 kg ha^{-1}). The N_1C_2 combination recorded the lowest seed yield of 0.9278 g/plant, 27.72 g/plot and 176 kg ha^{-1} for the first crop while in the second crop the seed yields were 1.33 g/plant, 108 g/plot and 685.7 kg ha^{-1}.

A significant effect was observed with respect to phosphorus and cutting interaction (Table 24b). The highest seed yield was recorded by P_3C_0 for the first crop (4.79 g/plant, 151.5 g/plot and 961.9 kg ha^{-1}) and for the second crop (5.43 g/plant, 178 g/plot and 1132 kg ha^{-1}). The lowest seed yield was recorded by P_1C_2 for the first crop (1.87 g/plant, 44.67 g/plot and 283.6 kg ha^{-1}) and for the second crop (2.38 g/plant, 53.42 g/plot and 339.2 kg ha^{-1}).

The NP and cutting interaction was also found to be significant (Table 24d). The $N_3P_3C_0$ combination gave the highest seed yield of 6.85 g/plant, 217.5 g/plot and 1380.9 kg ha^{-1} for the first crop. For the second crop the values were 7.63 g/plant, 242.3 g/plot and 1538.4 kg ha^{-1}. The $N_1P_1C_2$ combination gave the minimum seed yield of 0.85 g/plant, 26.17 g/plot and 166.2 kg ha^{-1} for the first crop. For the second crop the corresponding values were 1.27 g/plant, 33.75 g/plot and 214.3 kg ha^{-1}.

Potassium and cutting interaction was also found to be significant (Table 24c). The K_3C_0 combination recorded the highest seed yield for first crop (4.82 g/plant, 150.7 g/plot and 956.8 kg ha^{-1}) and for second crop (5.39 g/plant, 178.1 g/plot and 1130.8 kg ha^{-1}). The minimum seed yield was recorded by K_0C_2 combination for first crop (1.87 g/plant, 44.67 g/plot and 283.6 kg ha^{-1}). For the second crop the values were 2.31 g/plant, 54.25 g/plot and 344.4 kg ha^{-1}.

Significance was observed with respect to NK and cutting interaction also (Table 24e). The highest seed yield was recorded by $N_3K_3C_0$ combination for first crop (6.87 g/plant, 215.8 g/plot and 1370.1 kg ha^{-1}). In the second crop the seed yields were 7.53 g/plant, 215.8 g/plot and 1370.1 kg ha^{-1}. The $N_1K_1C_2$ combination recorded the lowest seed yield of 0.88 g/plant, 25.83 g/plot and 164 kg ha^{-1} for the first crop while it was 1.2 g/plant, 34.42 g/plot and 218.5 kg ha^{-1} for the second crop.

The PK and cutting interaction was also found to be significant (Table 24f). The $P_3K_3C_0$ combination recorded the highest seed yield of 5.15 g/plant, 159.4 g/plot and 1012 kg ha^{-1} for the first crop. In the second crop the values were 5.72 g/plant, 188 g/plot and 1193.6 kg ha^{-1}. The $P_1K_1C_2$ combination gave the minimum seed yield for the first crop (1.73 g/plant, 43.17 g/plot and 274.1 kg ha^{-1}) and also for the second crop (2.25 g/plant, 51.83 g/plot and 329.1 kg ha^{-1}).

Table 23. Effect of cuttings on seed yield

Treatments	Weight of seeds					
	First crop			Second crop		
	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
C_0	4.486	142.6	905.397	5.106	169.00	1073.0
C_1	4.158	139.4	885.1	4.476	163.2	1036.2
C_2	2.004	46.94	298.0	2.472	56.52	358.8

(Duncan's Multiple Range Test)

Table 24a. Effect of nitrogen and cutting interaction on seed yield

Levels of N (kg ha^{-1})	Yield/plant (g)			Yield/plot (g)			Yield/ha (kg)		
	Number of cuttings			Number of cuttings			Number of cuttings		
	C_0	C_1	C_2	C_0	C_1	C_2	C_0	C_1	C_2
First crop									
50	2.44	2.23	0.928	87.58	85.56	27.72	556.0	543.2	176.0
100	4.52	2.24	1.978	134.9	132.7	46.33	856.5	842.5	294.2
150	6.49	6.01	3.11	205.3	200.0	66.78	1303.4	1269.8	423.99
Second crop									
50	3.11	2.46	1.33	108.0	104.6	36.08	685.7	664.1	229.1
100	4.93	4.52	2.45	167.8	162.1	56.25	1065.4	1029.2	357.1
150	7.28	6.45	3.64	231.1	222.8	77.22	1467.3	1414.6	490.3

(Duncan's Mutiple Range Test)

Table 24b. Effect of phosphorus and cutting interaction on seed yield

Levels of P_2O_5 (kg ha^{-1})	Yield/plant (g)			Yield/plot (g)			Yield/ha (kg)		
	Number of cuttings			Number of cuttings			Number of cuttings		
	C_0	C_1	C_2	C_0	C_1	C_2	C_0	C_1	C_2
First crop									
50	4.17	3.82	1.87	133.1	131.2	44.67	845.1	832.99	283.6
75	4.49	4.14	2.02	143.2	139.0	46.75	909.2	882.51	296.8
100	4.79	4.51	2.12	151.5	148.0	49.42	961.9	939.7	313.8
Second crop									
50	4.80	4.16	2.38	160.3	156.0	53.42	1017.7	990.4	339.2
75	5.08	4.46	2.47	168.4	162.6	56.86	1069.2	1032.3	361.0
100	5.43	4.82	2.56	178.3	171.0	59.28	1132.0	1085.7	376.4

(Duncan's Multiple Range Test)

Table 24c. Effect of potassium and cutting interaction on seed yield

Levels of K_2O (kg ha^{-1})	Yield/plant (g)			Yield/plot (g)			Yield/ha (kg)		
	Number of cuttings			Number of cuttings			Number of cuttings		
	C_0	C_1	C_2	C_0	C_1	C_2	C_0	C_1	C_2
First crop									
50	4.17	3.93	1.87	134.3	132.4	44.89	852.7	840.6	285.0
75	4.46	4.11	1.99	142.9	139.3	46.78	907.3	884.4	297.0
100	4.82	4.43	2.16	150.7	146.6	49.17	956.8	930.76	312.18
Second crop									
50	4.84	4.20	2.31	160.9	156.0	54.25	1021.6	990.4	344.4
75	5.08	4.46	2.46	168.0	163.2	56.42	1066.6	1036.2	358.2
100	5.39	4.77	2.66	178.1	170.4	58.89	1130.8	1081.9	373.89

(Duncan's Multiple Range Test)

Table 24d. Effect of NP and cutting interaction on seed yield

Levels of $N : P_2O_5$ (kg ha^{-1})	Yield/plant (g)			Yield/plot (g)			Yield/ha (kg)		
	Number of cuttings			Number of cuttings			Number of cuttings		
	C_0	C_1	C_2	C_0	C_1	C_2	C_0	C_1	C_2
First crop									
50 : 50	2.3	1.83	0.85	82.67	79.5	26.17	524.9	504.8	166.2
50 : 75	2.43	2.22	0.95	87.83	85.5	27.33	557.6	542.8	173.5
50 : 100	2.60	2.63	0.98	92.25	91.67	29.67	585.7	582.0	188.4
100 : 50	3.98	3.95	1.83	121.7	125.0	43.33	772.7	793.6	275.0
100 : 75	4.63	4.25	2.00	138.3	133.1	46.67	878.1	845.1	296.3
100 : 100	4.93	4.52	2.10	144.8	139.9	49.00	919.3	888.2	311.1
150 : 50	6.23	5.68	2.93	195.0	189.2	64.50	1238.1	1201.2	409.5
150 : 75	6.40	5.97	3.10	203.5	198.5	66.25	1292.0	1260.3	420.6
150 : 100	6.85	6.37	3.28	217.5	212.3	69.58	1380.9	1347.9	441.8
Second crop									
50 : 50	2.93	2.18	1.27	102.2	97.2	33.75	648.9	617.12	214.3
50 : 75	3.08	2.45	1.37	106.6	103.0	36.08	676.8	653.9	229.1
50 : 100	3.32	2.75	1.35	115.2	113.0	38.42	731.4	717.4	243.9
100 : 50	4.50	4.17	2.38	157.3	154.8	52.33	998.7	982.8	332.2
100 : 75	4.93	4.55	2.45	168.9	161.8	56.92	1072.3	1027.3	361.4
100 : 100	5.35	4.83	2.52	177.3	169.7	59.5	1125.7	1077.4	377.8
150 : 50	6.97	6.12	3.50	221.4	215.3	74.17	1405.7	1366.9	470.9
150 : 75	7.23	6.37	3.60	229.7	222.8	77.58	1458.4	1414.6	492.6
150. 100	7.63	6.87	3.82	242.3	230.3	79.92	1538.4	1462.2	507.4

(Duncan's Multiple Range Test)

Table 24e. Effect of NK and cutting interaction on seed yield

Levels of $N:K_2O$ (kg ha^{-1})	Yield/plant (g)			Yield/plot (g)			Yield/ha (kg)		
	Number of cuttings			Number of cuttings			Number of cuttings		
	C_0	C_1	C_2	C_0	C_1	C_2	C_0	C_1	C_2
First crop									
50 : 50	2.13	2.00	0.88	83.33	80.33	25.83	529.1	510.0	164.0
50 : 75	2.4	2.22	0.87	87.83	85.17	27.67	557.6	540.7	175.7
50 : 100	2.8	2.47	1.03	91.58	91.17	29.67	581.4	578.8	188.4
100 : 50	4.22	4.05	1.82	124.2	125.6	44.17	788.5	797.4	280.4
100 : 75	4.53	4.2	2.00	136.0	132.4	46.33	863.5	840.6	294.1
100 : 100	4.8	4.47	2.12	144.7	140.0	48.5	918.7	888.9	307.9
150 : 50	6.17	5.75	2.9	195.3	191.3	64.67	1240.0	1214.6	410.6
150 : 75	6.45	5.92	3.1	204.8	200.2	66.33	1300.3	1271.1	421.1
150 : 100	6.87	6.35	3.32	215.8	208.5	69.33	1370.1	1323.8	440.2
Second crop									
50 : 50	2.85	2.2	1.2	100.5	97.33	34.42	638.1	617.9	218.5
50 : 75	3.08	2.43	1.28	107.0	104.7	36.00	679.3	664.7	228.6
50 : 100	3.4	2.75	1.5	116.4	111.9	37.83	739.0	710.5	240.2
100 : 50	4.6	4.25	2.3	158.8	154.8	54.08	1008.2	982.8	343.4
100 : 75	4.93	4.53	2.45	167.9	161.7	56.00	1066.0	1026.6	355.5
100 : 100	5.25	4.77	2.6	176.8	169.8	58.67	1122.5	1078.1	372.5
150 : 50	7.08	6.15	3.42	223.3	215.9	74.25	1417.7	1370.7	471.41
150 : 75	7.22	6.42	3.63	229.1	223.2	77.25	1454.6	1417.1	490.5
150 : 100	7.53	6.78	3.87	242.9	229.3	80.17	1542.2	1455.8	509.0

(Duncan's Multiple Range Test)

Table 24f. Effect of PK and cutting interaction on seed yield

Levels of P_2O_5:K_2O (kg ha^{-1})	Yield/plant (g)			Yield/plot (g)			Yield/ha (kg)		
	Number of cuttings			Number of cuttings			Number of cuttings		
	C_0	C_1	C_2	C_0	C_1	C_2	C_0	C_1	C_2
First crop									
50 : 50	4.02	3.7	1.73	127.3	125.8	43.17	808.2	798.7	274.1
50 : 75	4.12	3.77	1.87	132.0	131.3	44.17	838.1	833.6	280.4
50 : 100	4.38	4.00	2.02	140.0	136.5	46.67	888.9	866.6	296.3
75 : 50	4.07	3.85	1.87	132.8	130.4	44.33	843.1	827.9	281.5
75 : 75	4.47	4.13	2.00	144.2	139.5	46.75	915.5	885.7	296.8
75 : 100	4.93	4.45	2.18	152.7	147.2	49.17	969.5	934.6	312.2
100 : 50	4.43	4.25	2.00	142.7	141.0	47.17	906.0	895.2	299.5
100 : 75	4.8	4.43	2.1	152.5	146.9	49.42	968.2	932.7	313.8
100 : 100	5.15	4.83	2.27	159.4	156.0	51.67	1012.0	990.4	328.1
Second crop									
50 : 50	4.63	4.02	2.25	155.3	150.7	51.83	986.0	956.8	329.1
50 : 75	4.68	4.08	2.35	156.8	155.3	53.00	995.5	986.0	336.5
50 : 100	5.08	4.37	2.55	168.7	161.9	55.42	1071.1	1027.9	351.9
75 : 50	4.75	4.1	2.3	159.2	155.0	54.17	1010.8	984.1	343.9
75 : 75	5.12	4.53	2.52	168.5	162.3	57.00	1069.8	1030.4	361.9
75 : 100	5.38	4.73	2.6	177.5	170.3	59.42	1126.9	1081.2	377.3
100 : 50	5.15	4.48	2.37	168.1	162.3	56.75	1067.3	1030.4	360.3
100 : 75	5.43	4.77	2.5	178.7	171.8	59.25	1134.6	1090.8	376.2
100 : 100	5.72	5.2	2.82	188.0	178.8	61.83	1193.6	1135.2	392.6

(Duncan's Multiple Range Test)

4.5 Seed quality

4.5.1 Hundred seed weight

'F' test revealed no significant differences in the weight of 100 seeds among the various treatment combinations. The data on main effects are presented in Tables 25 and 28 and the analysis of variance in Appendices XV, XVI and XVII. There was no significant difference between control value and that of treatment combinations for this character. The extent of cutting did not influence 100 seed weight significantly.

4.6 Seed germination

The data on main effects on seed germination are presented in Tables 26 and 28 and the analysis of variance in Appendices XVIII and XIX.

Influence of the three nutrient levels on mean germination per cent was found to be insignificant. The treatment combinations did not differ from controls for germination per cent. The number of cuttings (C_0, C_1 and C_2) did not influence seed germination significantly.

4.7 Seed vigour

Vigour index of seedlings were calculated for both the seasons. The data on main effects are presented in Table 27 and the analysis of variance in Appendices XX and XXI.

It was observed that none of the nutrient levels influenced significantly the vigour index of seedlings. The treatment combinations also did not show any

Table 25. Effect of nitrogen, phosphorus and potassium on 100 seed weight

Treatments	Weight of 100 seeds (g)					
	Plants with no vegetable harvest		Plants with one vegetable harvest		Plants with two vegetable harvests	
	First crop	Second crop	First crop	Second crop	First crop	Second crop
Levels of N (kg ha^{-1})						
50	0.081	0.081	0.081	0.081	0.081	0.081
100	0.081	0.081	0.081	0.081	0.081	0.081
150	0.081	0.081	0.081	0.081	0.081	0.081
'F' test	NS	NS	NS	NS	NS	NS
Sem±	1.519×10^{-04}	1.9608×10^{-04}	2.051×10^{-04}	2.1926×10^{-04}	2.1388×10^{-04}	1.8473×10^{-04}
CD(0.05)	-	-	-	-	-	-
Levels of P_2O_5 (kg ha^{-1})						
50	0.081	0.081	0.081	0.081	0.081	0.081
75	0.081	0.081	0.081	0.081	0.081	0.081
100	0.081	0.081	0.081	0.081	0.081	0.081
'F' test	NS	NS	NS	NS	NS	NS
SEm±	1.519×10^{-04}	1.9608×10^{-04}	2.051×10^{-04}	2.1926×10^{-04}	2.1388×10^{-04}	1.8473×10^{-04}
CD(0.05)	-	-	-	-	-	-
Levels of K_2O (kg ha^{-1})						
50	0.081	0.081	0.081	0.081	0.081	0.081
75	0.081	0.081	0.081	0.081	0.081	0.081
100	0.081	0.081	0.081	0.081	0.081	0.081
'F' test	NS	NS	NS	NS	NS	NS
SEm±	1.519×10^{-04}	1.9608×10^{-04}	2.051×10^{-04}	2.1926×10^{-04}	2.1388×10^{-04}	1.8473×10^{-04}

Table 26. Effect of nitrogen, phosphorus and potassium on germination (%)

Treatments	Mean germination (%)					
	Plants with no vegetable harvest		Plants with one vegetable harvest		Plants with two vegetable harvests	
	First crop	Second crop	First crop	Second crop	First crop	Second crop
Levels of N (kg ha^{-1})						
50	71.53	71.61	71.61	71.94	72.03	72.11
100	72.00	71.97	71.83	71.89	72.06	71.67
150	71.86	72.00	71.94	71.67	71.94	71.94
`F' test	NS	NS	NS	NS	NS	NS
SEm±	0.2037	0.2514	0.2349	0.2507	0.2513	0.1915
CD(0.05)	-	-	-	-	-	-
Levels of P_2O_5 (kg ha^{-1})						
50	71.58	71.69	71.86	71.88	72.22	72.92
75	71.86	72.28	71.86	71.72	71.81	71.92
150	71.94	71.61	71.64	71.88	72.00	71.89
`F' test	NS	NS	NS	NS	NS	NS
SEm±	0.2037	0.2514	0.2349	0.2507	0.2513	0.1915
CD(0.05)	-	-	-	-	-	-
Levels of K2O (kg ha^{-1})						
50	71.86	71.69	71.52	71.78	71.83	71.69
75	71.97	71.91	71.55	71.86	72.19	72.06
100	71.55	71.97	72.03	71.86	72.00	71.97
`F' test	NS	NS	NS	NS	NS	NS
SEm±	0.2037	0.2514	0.2349	0.2507	0.2513	0.1915
CD (0.05)	-	-	-	-	-	-

Table 27. Effect of nitrogen, phosphorus and potassium on vigour index of seedlings

Treatments	Vigour index of seedlings					
	Plants with no vegetable harvest		Plants with one vegetable harvest		Plants with two vegetable harvests	
	First crop	Second crop	First crop	Second crop	First crop	Second crop
Levels of N (kg ha^{-1})						
50	524.71	524.31	525.50	526.76	527.75	527.99
100	526.36	526.16	526.34	525.95	527.19	527.10
150	525.74	525.56	527.16	526.71	527.98	526.55
'F' test	NS	NS	NS	NS	NS	NS
SEm±	1.3426	1.5581	1.5383	1.6829	1.4879	1.2587
CD(0.05)	-	-	-	-	-	-
Levels of P_2O_5 (kg ha^{-1})						
50	524.50	524.93	527.15	525.93	528.79	526.139
75	525.98	525.19	525.34	525.92	527.37	528.17
100	526.33	525.91	526.51	527.56	526.75	527.33
'F' test	NS	NS	NS	NS	NS	NS
SEm±	1.3426	1.5581	1.5383	1.6829	1.4879	1.2587
CD(0.05)	-	-	-	-	-	-
Levels of K_2O (kg ha^{-1})						
50	525.73	524.92	524.71	526.73	527.59	525.72
75	526.17	525.36	525.09	525.33	528.58	529.97
100	524.92	525.75	529.19	527.35	526.75	525.95
'F' test	NS	NS	NS	NS	NS	NS
SEm±	1.3426	1.5581	1.5383	1.6829	1.4879	1.2587
CD(0.05)	-	-	-	-	-	-

Table 28. Effect of cuttings on seed quality parameters

Treatments	Weight of 100 seeds (g)		Mean germination per cent		Vigour index of seedlings	
	First crop	Second crop	First crop	Second crop	First crop	Second crop
C_0	0.08069	0.0808	71.52	72.19	526.3	528.6
C_1	0.08091	0.08098	71.88	70.97	529.3	524.2
C_2	0.08106	0.08094	72.01	71.91	525.6	526.5

(Duncan's Multiple Range Test)

significant difference from control. There was no significant difference between the different number of cuttings. The different number of cuttings (C_0, C_1 and C_2) were found to be on par with each other (Table 28).

4.8 Benefit-cost ratio

4.8.1 Benefit-cost ratio of plants with no vegetable harvest

4.8.1.1 Main effects of NPK

The data on the main effects are presented in Table 29 and the analysis of variance in Appendix XXII.

There was a highly significant increase in BCR with the increase in nitrogen levels in both the crops. The N_3 level of nitrogen recorded the highest BCR of 2.41 for the first crop and 2.71 for the second crop. The BCR for the N_3 level of nitrogen was significantly more than N_2 level. (1.88 and 2.19 for the first and the second crops respectively). The N_2 level was followed by N_1 level which had the ratio of 1.41 for the first crop and 1.71 for the second crop. All the three nitrogen levels significantly effected higher BCR than the control which recorded a value of 1.00 for first crop and 1.29 for second crop.

The three levels of phosphorus (P_1, P_2 and P_3) recorded higher BCR than the control for both crops. The highest BCR was recorded by P_3 level for the first crop (2.00) and for the second crop (2.31). In this respect the P_3 level was significantly superior to P_2 level which recorded the ratio 1.9 for the first crop and 2.21 for the second crop. The effect of P_2 level was followed by P_1 level which recorded a BCR of 1.79 and 2.1 respectively for the first and the second crops.

Table 29. Influence of nitrogen, phosphorus and potassium on benefit-cost ratio

Treatments	BCR					
	Plants with no vegetable harvest		Plants with one vegetable harvest		Plants with two vegetable harvests	
	First crop	Second crop	First crop	Second crop	First crop	Second crop
Levels of N (kg ha^{-1})						
50	1.41	1.71	1.57	1.86	1.23	1.46
100	1.88	2.19	2.04	2.34	1.61	1.86
150	2.41	2.71	2.55	2.85	2.09	2.36
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.014	0.01483	0.01424	0.0178	0.01235	0.014023
CD(0.05)	0.0407	0.043	0.0413	0.0516	0.03585	0.04069
Levels of P_2O_5 (kg ha^{-1})						
50	1.79	2.097	1.95	2.25	1.54	1.80
75	1.9	2.211	2.05	2.35	1.65	1.90
100	2.0	2.309	2.16	2.46	1.73	1.99
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.014	0.01483	0.01424	0.0178	0.01235	0.014023
CD(0.05)	0.0407	0.043	0.0413	0.0516	0.03585	0.04069
Levels of K_2O (kg ha^{-1})						
50	1.82	2.13	1.98	2.28	1.57	1.82
75	1.89	2.202	2.05	2.35	1.64	1.89
100	1.97	2.286	2.13	2.43	1.72	1.97
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm±	0.014	0.01483	0.01424	0.0178	0.01235	0.014023
CD(0.05)	0.0407	0.043	0.0413	0.0516	0.03585	0.04069

The potassium levels also recorded higher BCR than the control. The highest BCR was recorded under K_3 level in the first crop (1.97) and in the second crop (2.29). This was followed by K_2 level (1.89 for the first crop and 2.20 for the second crop). The K_2 level was superior to K_1 level (1.82 and 2.13 for the first and the second crops respectively).

4.8.1.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops (Table 30a). The N_3P_3 combination recorded the highest BCR of 2.52 and 2.83 for the first and second crops respectively where as N_1P_1 combination recorded the lowest ratio of 1.31 for the first crop and 1.61 for the second crop. Among the nitrogen and potassium combinations, N_3K_3 recorded the highest BCR of 2.48 for the first crop and 2.79 for the second crop (Table 30b). The N_1K_1 combination recorded the lowest BCR of 1.33 for the first crop and 1.64 for the second crop. Phosphorus and potassium interactions were also significant (Table 30c). The highest BCR was recorded by P_3K_3 for the first crop (2.08) and for the second crop (2.38). The lowest BCR was registered by the combination P_1K_1 (1.72 for the first crop and 2.03 for the second crop).

4.8.2 Benefit-cost ratio of plants with one vegetable harvest

4.8.2.1 Main effects of NPK

The data on the main effects are presented in Table 29 and the analysis of variance in Appendix XXII.

Table 30a. Influence of N x P interaction on benefit-cost ratio

Levels of N (kg ha^{-1})	BCR											
	Plants with no vegetable harvest				Plants with one vegetable harvest				Plants with two vegetable harvests			
	Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})				Levels of P_2O_5 (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	1.31	1.40	1.51	1.41	1.47	1.56	1.67	1.57	1.14	1.25	1.30	1.23
100	1.77	1.90	1.98	1.88	1.93	2.05	2.13	2.04	1.51	1.61	1.70	1.61
150	2.29	2.41	2.52	2.41	2.44	2.55	2.67	2.55	1.98	2.09	2.21	2.09
Mean	1.79	1.9	2.0		1.95	2.05	2.16		1.54	1.65	1.73	
SEm±	0.02428				0.02466				0.0214			
CD(0.05)	0.070				0.0716				0.062			
Second crop												
50	1.61	1.71	1.82	1.71	1.77	1.87	1.96	1.86	1.41	1.47	1.51	1.46
100	2.08	2.20	2.29	2.19	2.24	2.34	2.44	2.34	1.74	1.88	1.97	1.86
150	2.60	2.72	2.83	2.71	2.74	2.85	2.97	2.85	2.25	2.36	2.48	2.36
Mean	2.097	2.211	2.309		2.25	2.35	2.46		1.8	1.9	1.99	
SEm±	0.02569				0.03082				0.0243			
CD(0.05)	0.0746				0.089				0.070			

Table 30b. Influence of N x K interaction on benefit-cost ratio

Levels of N (kg ha^{-1})	BCR											
	Plants with no vegetable harvest				Plants with one vegetable harvest				Plants with two vegetable harvests			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	1.33	1.40	1.49	1.41	1.50	1.56	1.65	1.57	1.17	1.22	1.30	1.23
100	1.80	1.89	1.96	1.88	1.96	2.04	2.11	2.04	1.53	1.60	1.70	1.61
150	2.33	2.40	2.48	2.41	2.48	2.56	2.63	2.55	2.02	2.09	2.17	2.09
Mean	1.82	1.89	1.97		1.98	2.05	2.13		1.57	1.64	1.72	
SEm±	0.02428				0.02466				0.0214			
CD(0.05)	0.070				0.0716				0.062			
Second crop												
50	1.64	1.70	1.79	1.71	1.81	1.84	1.94	1.86	1.4	1.45	1.54	1.46
100	2.11	2.20	2.27	2.19	2.25	2.35	2.42	2.34	1.78	1.86	1.95	1.86
150	2.64	2.71	2.79	2.71	2.77	2.86	2.93	2.85	2.28	2.36	2.44	2.36
Mean	2.13	2.20	2.286		2.28	2.35	2.43		1.82	1.89	1.97	
SEm±	0.02569				0.03082				0.0243			
CD(0.05)	0.0746				0.089				0.070			

Table 30c. Influence of P x K interaction on benefit-cost ratio

Levels of P_2O_5 (kg ha^{-1})	BCR											
	Plants with no vegetable harvest				Plants with one vegetable harvest				Plants with two vegetable harvests			
	Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})				Levels of K_2O (kg ha^{-1})			
	50	75	100	Mean	50	75	100	Mean	50	75	100	Mean
First crop												
50	1.72	1.79	1.86	1.79	1.88	1.95	2.00	1.95	1.49	1.53	1.61	1.54
75	1.81	1.91	2.00	1.9	1.95	2.06	2.15	2.05	1.54	1.66	1.74	1.65
100	1.94	1.99	2.08	2.0	2.10	2.14	2.22	2.16	1.68	1.72	1.80	1.73
Mean	1:82	1.89	1.97		1.98	2.05	2.13		1.57	1.64	1.72	
SEm±	0.02428				0.02466				0.0214			
CD(0.05)	0.070				0.0716				0.062			
Second crop												
50	2.03	2.09	2.17	2.097	2.18	2.25	2.32	2.25	1.74	1.80	1.86	1.8
75	2.11	2.21	2.31	2.211	2.24	2.36	2.45	2.35	1.79	1.91	2.00	1.9
100	2.25	2.3	2.38	2.309	2.41	2.43	2.53	2.46	1.93	1.97	2.06	1.99
Mean	2.13	2.20	2.286		2.28	2.35	2.43		1.82	1.89	1.97	
SEm±	0.02569				0.03082				0.0243			
CD(0.05)	0.0746				0.089				0.070			

Nitrogen had highly significant effect in BCR. The highest BCR was recorded under N_3 level (2.55 and 2.85 for first and second crops respectively). This was followed by N_2 level which had a value of 2.03 for first crop and 2.34 for second crop. The N_2 nitrogen level was significantly superior to N_1 for higher BCR (1.57 for first crop and 1.86 for second crop). All the three nitrogen levels effected significantly higher BCR than the control (1.15 and 1.40 for first and second crops respectively).

In both the crops, the phosphorus levels recorded higher BCR than the control. The P_3 level recorded the highest BCR of 2.16 for the first crop and 2.46 for the second crop. This was followed by P_2 (2.05 for the first crop and 2.35 for the second crop). The P_2 level was superior to P_1 level which recorded a BCR of 1.95 and 2.25 for the first and second crops respectively.

The potassium levels also recorded higher BCR than the control. The highest BCR was recorded under K_3 level in the first crop (2.13) and in the second crop (2.43). The K_3 level effected significantly higher BCR than K_2 level which recorded the ratio at 2.05 for the first crop and 2.35 for the second crop. The effect of K_2 level was followed by K_1 level which had a BCR of 1.98 and 2.3 respectively for first and second crops.

4.8.2.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops (Table 30a). The highest BCR of 2.67 for the first crop and 2.97 for the second crop was recorded under N_3P_3. The N_1P_1 combination recorded the lowest values of 1.47 for the first crop and 1.77 for the second crop. Nitrogen and potassium interactions were also significant (Table 30b). The highest BCR was recorded by N_3K_3 for the first crop (2.63) and for the second crop (2.93). The lowest BCR was registered in the combination N_1K_1 (1.5 and 1.81 for first and second crops respectively). Among the phosphorus and potassium combination, P_3K_3 recorded the highest BCR of 2.22 and 2.53 for first and second crops respectively. The P_1K_1 combination recorded the lowest BCR of 1.88 for the first crop and 2.18 for the second crop.

4.8.3 Benefit-cost ratio of plants with two vegetable harvests

4.8.3.1 Main effects of NPK

The data on the main effects are presented in Table 29 and the analysis of variance in Appendix XXII.

In both the crops, the BCR increased significantly with the increase in nitrogen level. The N_3 level of nitrogen recorded the highest BCR of 2.09 and 2.36 respectively for the first and the second crops. This was followed by N_2 level (1.61 for the first crop and 1.86 for the second crop). The N_2 level was significantly superior to N_1 which recorded the ratio of 1.23 and 1.46 for first and second crops respectively. All these nitrogen levels were significantly superior to control which had the BCR 0.93 for the first crop and 1.15 for the second crop.

The three levels of phosphorus recorded higher BCR than the control for both the crops. The highest BCR was recorded by P_3 level for the first crop (1.73) and for the second crop (1,99). The P_3 level was significantly superior to P_2 level which recorded the BCR of 1.65 and 1.90 for the first and second crops respectively. The effect of P_2 level was followed by P_1 level with a value of 1.54 for the first crop and 1.80 for the second crop.

The potassium levels also recorded higher BCR than the control. The highest BCR was recorded under K_3 level in the first crop (1.72) and in the second crop (1.97). This was followed by K_2 (1.64 for the first crop and 1.89 for the second crop). The K_2 level was superior to K_1 level which recorded a BCR of 1.57 and 1.82 for first and second crops respectively.

4.8.3.2 Interaction effects of NPK

Nitrogen and phosphorus interactions were significant for both the crops (Table 30a). The N_3P_3 combination recorded the highest BCR (2.21 and 2.48 for the first and second crops respectively). The N_1P_1 combination recorded the lowest values of 1.14 for the first crop and 1.41 for the second crop. Among the nitrogen and potassium combinations, N_3K_3 recorded the highest BCR of 2.17 for the first crop and 2.40 for the second crop (Table 30b). The N_1K_1 combination recorded the lowest BCR of 1.17 for the first crop and 1.4 for the second crop. Phosphorus and potassium interactions were also significant for this parameter (Table 30c). The highest BCR was recorded by P_3K_3 for the first crop (1.80) and for the second crop (2.06). The lowest BCR was given by P_1K_1 (1.49 and 1.74 for the first and second crops respectively).

Comparison of the effect of cuttings on BCR were also done. The analysis of variance is presented in Appendix XXII. The significance was tested using DMRT and the results are as follows.

Among the different number of cuttings (C_0, C_1 and C_2), C_1 recorded the highest BCR of 2.05 for the first crop and 2.35 for the second crop (Table 31). The C_1 (one vegetable harvest) was significantly superior to C_0 (no vegetable

Table 31. Influence of cuttings on benefit-cost ratio

Treatments	BCR	
	First crop	Second crop
C_0	1.899	2.206
C_1	2.052	2.352
C_2	1.643	1.896

(Duncan's Multiple Range Test)

harvest), the latter had a value of 1.90 and 2.21 for the first and second crops respectively. The C_0 was followed by C_2 (two vegetable harvests) which recorded the BCR 1.64 for the first crop and 1.90 for the second crop.

The nitrogen levels and cutting interactions were significant for both the crops (Table 32a). The N_3C_1 combination recorded the highest BCR of 2.56 for the first crop and 2.85 for the second crop. The N_1C_2 combination recorded the lowest values for BCR (1.41 for the first crop and 1.71 for the second crop). Among the phosphorus and cutting combinations, P_3C_1 recorded the highest BCR of 2.16 and 2.45 for the first and second crops respectively (Table 32b). The P_1C_2 combination recorded the lowest BCR of 1.79 and 2.1 respectively for the first and second crops. The NP and cutting interactions were also found to be significant for both the crops (Table 32c). The highest BCR of 2.67 for the first crop and 2.97 for the second crop were recorded under $N_3P_3C_1$. The $N_1P_1C_2$ combination recorded the lowest values of 1.14 and 1.40 for the first and second crops respectively.

Significance was observed with respect to potassium and cutting interaction (Table 32d). The highest BCR was recorded under K_3C_1 for the first crop (2.13) and for the second crop (2.43). The lowest BCR of 1.57 and 1.82 for the first and second crops respectively were recorded under K_1C_2. Among the NK and cutting combinations, $N_3K_3C_1$ recorded the highest BCR of 2.63 for the first crop. It was 2.93 for the second crop (Table 32e). The $N_1K_1C_2$ combination recorded the lowest BCR of 1.17 for the first crop and 1.4 for the second crop. The PK and cutting interactions were also found to be significant for both the crops (Table 32f). The highest BCR of 2.22 for the first crop and 2.53 for the second crop were recorded under $P_3K_3C_1$. The $P_1K_1C_2$ combination recorded the lowest BCR of 1.49 and 1.74 for the first and second crops respectively.

Table 32a. Influence of nitrogen and cutting interaction on benefit-cost ratio

Levels of N (kg ha^{-1})	Number of cuttings in first crop			Number of cuttings in second crop		
	C_0	C_1	C_2	C_0	C_1	C_2
50	1.406	1.567	1.229	1.714	1.864	1.464
100	1.884	2.036	1.606	2.191	2.340	1.863
150	2.406	2.555	2.093	2.713	2.854	2.362

(Duncan's Multiple Range Test)

Table 32b. Influence of phosphorus and cutting interaction on benefit-cost ratio

Levels of P_2O_5 (kg ha^{-1})	Number of cuttings in first crop			Number of cuttings in second crop		
	C_0	C_1	C_2	C_0	C_1	C_2
50	1.789	1.947	1.545	2.097	2.249	1.801
75	1.903	2.053	1.649	2.211	2.351	1.902
100	2.003	2.157	1.734	2.309	2.458	1.986

(Duncan's Multiple Range Test)

Table 32c. Influence of NP and cuttings interaction on benefit-cost ratio

Levels of N : P_2O_5 (kg ha^{-1})	Number of cuttings in first crop			Number of cuttings in second crop		
	C_0	C_1	C_2	C_0	C_1	C_2
50:50	1.307	1.472	1.144	1.613	1.768	1.409
50:75	1.404	1.559	1.247	1.714	1.865	1.468
50:100	1.506	1.669	1.296	1.815	1.958	1.514
100:50	1.770	1.928	1.514	2.081	2.237	1.744
100:75	1.898	2.052	1.608	2.204	2.343	1.878
100:100	1.984	2.128	1.696	2.288	2.440	1.968
150:50	2.290	2.443	1.976	2.598	2.741	2.249
150:75	2.408	2.549	2.093	2.716	2.846	2.360
150:100	2.520	2.672	2.210	2.825	2.974	2.477

(Duncan's Multiple Range Test)

Table 32d. Influence of K and cuttings interaction in benefit-cost ratio

Levels of K_2O (kg ha^{-1})	Number of cuttings in first crop			Number of cuttings in second crop		
	C_0	C_1	C_2	C_0	C_1	C_2
50	1.823	1.977	1.572	2.130	2.275	1.821
75	1.895	2.051	1.637	2.202	2.350	1.893
100	1.978	2.129	1.720	2.286	2.432	1.974

(Duncan's Multiple Range Test)

Table 32e. Influence of NK and cutting interaction on benefit-cost ratio

Levels of N : K_2O (kg ha^{-1})	Number of cuttings in first crop			Number of cuttings in second crop		
	C_0	C_1	C_2	C_0	C_1	C_2
50:50	1.334	1.497	1.171	1.643	1.806	1.400
50:75	1.399	1.555	1.218	1.704	1.843	1.453
50:100	1.485	1.648	1.297	1.794	1.943	1.537
100:50	1.801	1.957	1.525	2.107	2.247	1.781
100:75	1.887	2.043	1.597	2.196	2.350	1.862
100:100	1.964	2.107	1.696	2.269	2.424	1.947
150:50	2.333	2.477	2.019	2.640	2.773	2.283
150:75	2.399	2.555	2.095	2.706	2.857	2.364
150:100	2.484	2.630	2.165	2.793	2.931	2.439

(Duncan's Multiple Range Test)

Table 32f. Influence of PK and cutting interaction on benefit-cost ratio

Levels of P_2O_5:K_2O (kg ha^{-1})	Number of cuttings in first crop			Number of cuttings in second crop		
	C_0	C_1	C_2	C_0	C_1	C_2
50:50	1.721	1.882	1.489	2.029	2.179	1.743
50:75	1.789	1.950	1.530	2.093	2.251	1.795
50:100	1.859	2.010	1.615	2.170	2.317	1.863
75:50	1.807	1.946	1.545	2.114	2.236	1.794
75:75	1.905	2.060	1.661	2.214	2.364	1.912
75:100	1.997	2.153	1.742	2.305	2.454	2.000
100:50	1.941	2.103	1.682	2.248	2.411	1.927
100:75	1.991	2.143	1.719	2.299	2.435	1.972
100:100	2.077	2.224	1.801	2.381	2.526	2.060

(Duncan's Multiple Range Test)

Discussion

5. DISCUSSION

Amaranth is one of the large and taxonomically diverse groups of tropical leafy vegetables. They are excellent vegetables for their fast growing nature, with an extremely high yield potential, lower susceptibility to soil borne diseases than many other vegetables, suitability for crop rotation with any other vegetable crop and for its high mineral and nutrient content. Because of the low production cost and high yield, amaranth is one of the cheapest green leafy vegetables which is often described as "Poorman's vegetable".

Nutritionally amaranth is valued as excellent because of its high content of essential micronutrients. As a leafy vegetable it occupies an undisputed position in our dietary requirement especially in South India. The vitamin A deficiency which is the cause of malnutrition and deficiency diseases in Indian as well as in South Asian countries can be alleviated substantially if the daily intake is enhanced. It helps in easy bowl movement and increases the eyesight. Despite the high degree of nutritive value the main constraint in their nutritional exploitation is the presence of anti-nutritional factors like oxalates and nitrates. The present levels of oxalates and nitrates however, do not pose a nutritional problem under normal conditions of amaranth consumption. But changes in the level of these anti-nutritional factors can occur with the changes in management practices.

A genotype expresses its full when it is grown in a favourable environmental condition and the crop productivity is dependent on its nutrition. Being a leafy vegetable amaranth requires adequate nitrogen application which is an essential component in protoplasm, chlorophyll molecules, amino acids and nucleic acids. Nitrogen in reasonably adequate quantities is essential for balanced growth of the crops (Halfacre and Barden, 1979). Phosphorus fertilization is indispensable to get better economic yield in many crops. Crops vary in their response to phosphorus. Potassium is another major nutrient whose role is significant and is involved in photosynthesis, carbohydrate and protein metabolism and water relations of plants (Traynor, 1980). Potassium is needed for several yield forming processes in plants such as enzyme activation, water use, photosynthesis, transport of sugar, protein synthesis and starch synthesis (Agerton and Martin, 1980).

In amaranthus economic returns depend on type of cultivation and management practices. Seed production in amaranthus is taken up usually at the expense of vegetable yield. A reasonable number of vegetable harvest taken before the seed harvest ensures more profit for the amaranthus growers. The maximum returns from a seed crop depend on the optimum number of vegetable harvests taken before the crop is left for seed yield. In fact a seed crop requires more fertilization than a crop grown for vegetable purpose. It is imperative to fix up optimum fertilizer rate when one expects maximum returns from vegetable harvests and seed yield. The requisite information on this line is rather meagre. The present investigation was taken up in this background to study the effects of different levels of NPK on amaranth seed crop and to find out the optimum number of vegetable harvests that can be taken for maximum net returns. The quality of the greens and seeds as influenced by vegetable harvest was also investigated. The salient findings of the experiment are discussed hereunder.

5.1 Plant height

The plant height in amaranthus is indicative of the optimum time of harvest. Application of nitrogen showed a significant increase in plant height upto the highest level tried (150 kg ha^{-1}). Increase in plant height in amaranthus in response to nitrogen application was documented by many workers (Ramachandra, 1978; Keskar *et al.*, 1983; Singh *et al.*, 1985; Hilman and Abidin, 1987; Subhan, 1989 and Panda *et al.*, 1991). In the case of phosphorus also there was significant increase in plant height upto the highest level tried (100 kg ha^{-1}) though the extent of increase was less as compared to the effect of nitrogen. Similar observations were made by Ramachandra (1978), Panda *et al.* (1991) and Makus (1992). The response to potassium was also positive in increasing the plant height and was significant upto the highest level tried (100 kg). Similar trend in influence of potassium on plant height was reported in *Amaranthus tricolor* L. by Panda *et al.* (1991).

The predominant role of nitrogen to enhance vegetative growth is associated with high synthesis of biochemical substances which are essential for plant growth. Obviously the highest level of nitrogen in the present study did show a highly significant change. Significant increase in the height of plant due to phosphorus application might be due to presence of sufficient amount of phosphorus which have played good role towards rapid cell division and cell elongation in the meristematic region of the plant. Since potassium is involved in photosynthesis, carbohydrate and protein metabolism and water relations of plants, this has contributed favourably to increase plant height significantly.

All the two-factor interactions were significant. The general trend of nitrogen and phosphorus interaction was positive. A positive response in the case of plant height to nitrogen and phosphorus combination was also reported by Ramachandra (1978). Plant height in amaranthus is a character that is altered by availability of the three plant nutrients. In the present study there was significant increase in plant height with the increase in levels of NPK indicating the presence of sub-optimal level of nutrients in the soil before cropping. So it is evident that higher level of N at 150 kg ha^{-1}, P_2O_5 at 100 kg ha^{-1} and K_2O at 100 kg ha^{-1} are quite condusive for the growth and development of amaranthus.

5.2 Green yield

There was significant increase in green yield with the increase in levels of NPK. In the case of nitrogen, the green yield was found to increase upto 150 kg N ha^{-1}. The results thus indicate that nitrogen supplying power of the soil was inadequate to meet the requirement of the crop. There are two factors that affect the response of crops to fertilizers. These are the quantity of the concerned nutrient in the soil in the available form and the requirement of the crop. The significant increase in green yield noticed upto 150 kg N ha^{-1} indicates that the inherent rate of supply of nitrogen from the soil was not enough to meet the requirement of amaranthus. A similar increase in the green yield of amaranthus by the application of nitrogen was reported by Purushothaman (1978); Ramachandra (1978); Keskar *et al.* (1983); Singh *et al.* (1985); Hilman and Abidin (1987); Subhan (1989) and Panda *et al.* (1991).

As in the case of nitrogen there was significant positive response to the phosphorus application upto the highest level of 100 kg P_2O_5 ha^{-1}. But here the extent of increase in green yield was less when compared to nitrogen application. This can be attributed to the fact that the quantity of phosphorus available in the soil originally was lower than the quantity required by the crop. Similar results of increased response to applied phosphorus were reported by Ramachandra (1978) in *A. gangeticus*, Panda *et al.* (1991) and Makus (1992) in *A. tricolor* L.

Response to potassium application was significant upto the highest level of 100 kg K_2O ha^{-1} to realise green yield. This finding is supported by the observation of Panda *et al.* (1991) in *Amaranthus tricolor* L.. The interaction effects of the nutrients were generally significant. So the combined application of nutrients was found to be advantageous.

5.3 Quality of greens

Presence of anti-nutritional factors like oxalate and nitrate in amaranthus is pointed out as negative characters in quality assessment of greens especially when it is found in excess.

5.3.1 Oxalate content

Oxalate content in foods are of concern because free oxalates bind essential dietary divalent minerals primarily, calcium and make them nutritionally unavailable (Marderosian *et al.*, 1980). Even under normal dietic regimes, calcium deficiency is likely to occur in Indian diet especially among rice eating population (Srivastava and Krishnan, 1959). The oxalic acid levels in amaranth greens become high as the plants get older and when grown under dry conditions.

The range of values recorded for oxalate content (4.84%-7.3%) in this experiment were in line with those reported by Singh (1973), Mugerwa and Bwabye (1974), Mugerwa and Stafford (1976), Marderosian *et al.* (1980), Hill and Rawate

(1982), Sarah (1986) and Mallika (1987). Studies on the adverse nutritional effects due to higher intake of amaranth leaves have indicated that a consumption of more than 200 g/day can cause the formation of calcium oxalate stones in the human urinary system. Deutsch (1977) opined that healthy adult need not be concerned about the presence of these compounds as the leafy greens make up only a fraction of the daily food intake. The statistics of consumption indicate that the intake is only 18.8 g/person/day in many of the developing countries. This is definitely non-consequential as compared to 200 g required for causing nutritional defects due to the higher oxalate levels.

There was significant decrease in oxalate content due to the increasing levels of nitrogen. This may be because of the dilution of oxalates in plant tissues by increased growth resulting from nitrogen fertilization. This argument was already endorsed by Ehrendorfer (1961), Verma *et al.* (1969), Singh (1974) and Sarah (1986).

The role of phosphorus as evident from the fact that applied phosphorus had a significant depressing effect on the oxalate content. This may be because high P_2O_5 application obstructs oxalic acid formation so that the promoting effect of calcium cannot take effect. On the contrary there was significant increase in the oxalate content on increasing the levels of potassium. The observations are in confirmity with the findings on Grutz (1956) and Ehrendorfer (1961) who have reported that oxalic acid content decreased with increase in P_2O_5 application in spinach.

The quality comparison of the two crops showed that the oxalate accumulation in the second crop was higher than that of first crop. This difference is corroborated by the fact that the oxalate levels become high when the plants are grown under dry conditions (Deutsch, 1977 and Sarah, 1986).

5.3.2 Nitrate content

The levels of nitrate in the diet is of concern if it is converted to nitrite and then to nitrosamines. Dietary nitrate is normally absorbed through the digestive tract and is excreted through the urine without further conversion. However, the acidity of the digestive tract and the composition of the bacterial flora may lead to conversion of nitrate to nitrite. Nitrite is absorbed into the blood stream where it combines with haemoglobin to form methaemoglobin. If sufficiently high levels are reached, cyanosis and finally death can ensue.

The range of values recorded for nitrate content in the present study was 0.17%-0.74% which is almost in line with those reported by Schmidt (1971), Marderosian *et al.* (1980) and Devadas (1982). A clear cut increase in nitrate accumulation was noticed with increasing levels of nitrogen. The usual effect is that increasing the level of nitrogen nutrition increases the nitrate concentration of vegetables. The trend revealed in the present study is in agreement with the reports of earlier workers (Commoner, 1970; Barker and Maynard, 1971; Peek *et al.*, 1971; Trevino and Murray, 1975; Sarah, 1986 and Custic *et al.*, 1994). Phosphorus did not evince any significant effect on the nitrate accumulation. The influence of potassium was significant in increasing the nitrate content though the extent of increase was less as compared to the effect of nitrogen application. Among the two factor interactions, nitrogen and potassium interaction was found to be significant.

Between crops taken in two seasons, the nitrate accumulation in the second crop was higher than that of the first crop. The reason can be ascribed to the fact that when the plants are grown under higher temperature and dry conditions the nitrate levels become high (Barker *et al.*, 1971; Marderosian *et al.*, 1980 and Sarah, 1986).

5.4 Seed yield

Seed crop receiving more nitrogenous fertilizer produced more number of seeds per plant than that obtained in control. The number of seeds per plant increased with the increase in nitrogen and was maximum at the highest dose of nitrogen (150 kg N ha^{-1}). The higher dose of nitrogen seems to have resulted in greater synthesis of carbohydrate in plants which accelerated seed formation as compared to those which received lower amount of nitrogen. There was positive response to nitrogen upto 300 kg ha^{-1} in *Amaranthus hypochondriacus* (Reyes *et al.*, 1988). This was further confirmed in fenugreek where seed yield increased upto the highest level tried (Baboo and Sharma, 1995).

Similar to the effect of nitrogen, phosphorus application also had significant positive response upto the highest level applied (100 kg P_2O_5 ha^{-1}). However, the increase in seed yield with every additional dose of phosphorus was not to that extent as compared to increase with respect to nitrogen. The response to potassium application was significant upto the highest level (100 kg ha^{-1}) but the magnitude of increase in seed yield was lesser than that of nitrogen. This is in confirmity with the observation of Schmidth (1986) who reported an increase in grain yield of amaranth upto the highest level of three fertilizers applied

(150 kg ha^{-1} urea, 200 kg ha^{-1} TSP and 100 kg ha^{-1} KCl). The interactions were generally significant and the combined application of nutrients was found to be advantageous.

The effect of number of cuttings was found to be significant. No cutting gave significantly higher seed yield than one cutting or two cuttings. For the first crop, no cutting and one cutting recorded a gain in seed yield of 123 per cent and 107 per cent respectively over two cuttings (Fig.2). For the second crop, no cutting and one cutting recorded a gain in seed yield of 106.5 per cent and 81 per cent respectively over two cuttings. A similar trend was reported by Sinha *et al.* (1985) in palak wherein one cutting gave significantly higher yield than no cutting or more than one cutting. However, they also observed a drastic reduction in seed yield at higher number of cuttings. The reason attributed to this could be that the time left for shoot emergence and flowering was found shorter resulting in low seed yields. Frequent cutting also affects the vegetative growth and depletion of available nutrients in the plant.

5.5 Seed quality parameters

None of the three nutrients, NPK had any significant effect on the 100 seed weight, seed germination and seedling vigour. Cuttings also had no appreciable effect on these characters. This shows that seed filling and seed maturation will not be hampered by the clipping of vegetative part.

5.6 Benefit-cost ratio (BCR)

The effect of number of cuttings was found to be significant for this parameter. One cutting recorded significantly higher benefit-cost ratio than no

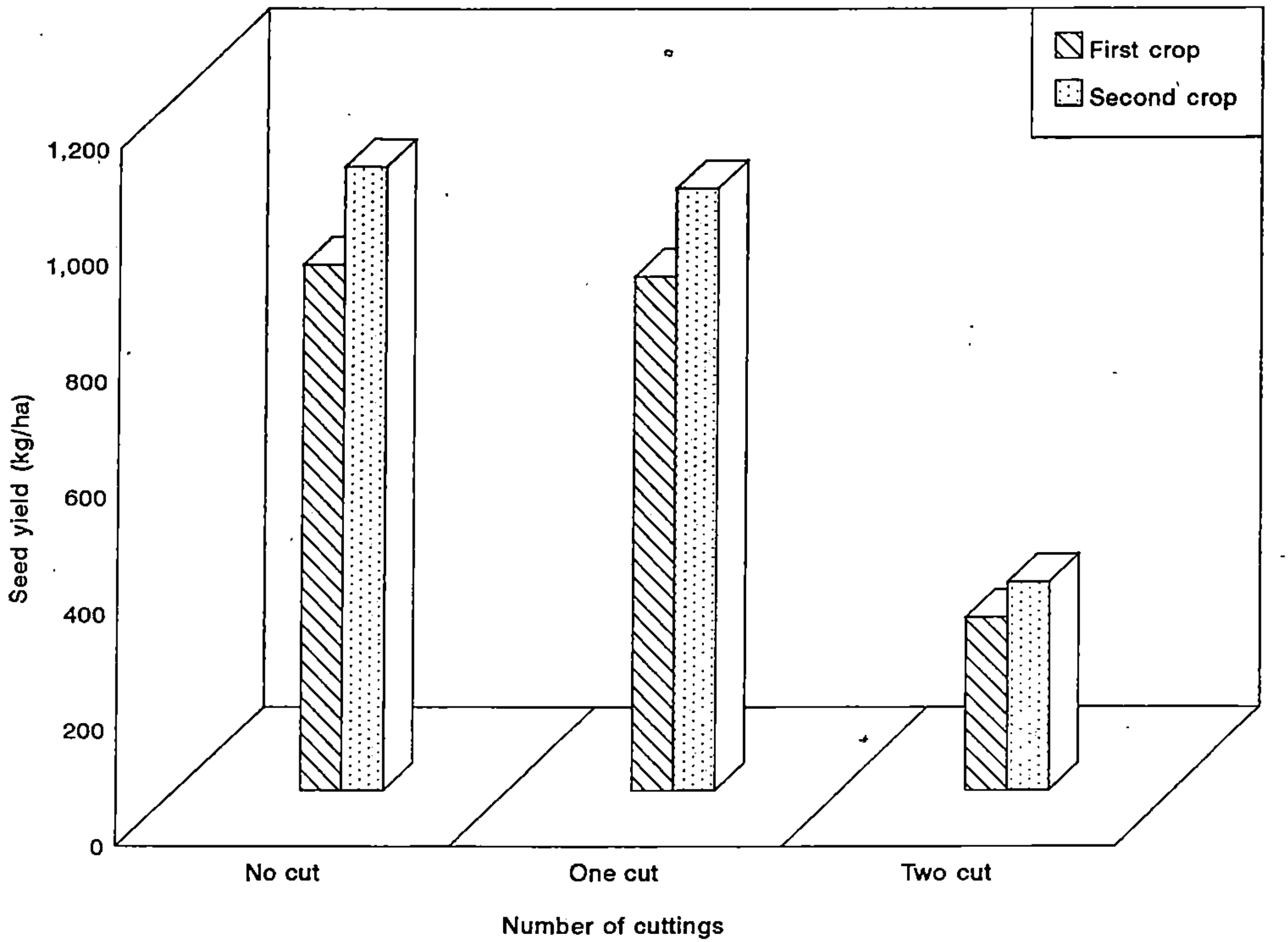

Fig.2. Effect of cuttings on seed yield (kg/ha)

cutting or two cuttings. For the first crop, one cutting and no cutting recorded a gain in benefit-cost ratio of 25 per cent (2.05) and 15.6 per cent (1.90) respectively over two cuttings (1.64). For the second crop, one cutting and no cutting recorded a gain in benefit-cost ratio of 24 per cent (2.35) and 16.4 per cent (2.21) respectively over two cuttings (1.90) (Fig.3). This is in confirmity with the findings of Salini (1975) and Sinha *et al.* (1985).

All the two-factor interactions were significant. Among the nitrogen and cutting interaction application of nitrogen at the highest level (150 kg ha^{-1}) resulted in a marked increase in benefit cost ratio when one cutting was taken (2.56 for the first crop and 2.85 for the second crop). Sinha *et al.* (1985) found a similar trend in palak where one cutting of green leaves gave the highest net return. Similarly among the phosphorus and cutting interaction, application of phosphorus at the highest level (100 kg ha^{-1}) resulted in highest benefit-cost ratio when one cutting was taken (2.16 for the first crop and 2.45 for the second crop). In the case of potassium x cutting interaction, the highest benefit-cost ratio was recorded under the highest level of potassium (100 kg ha^{-1}) when one cutting was taken (2.13 for the first crop and 2.43 for the second crop).

All the three-factor interactions were also found to be significant. Among the NP and cutting interactions, application of nitrogen and phosphorus at the highest levels (N 150 kg ha^{-1} and P_2O_5 100 kg ha^{-1}) recorded the highest benefit-cost ratio when one cutting was taken (2.67 for the first crop and 2.97 for the second crop). This is in confirmity with the report of Baboo and Sharma (1995). In the case of NK and cutting combinations, the highest benefit-cost ratio (2.63 for the first crop and 2.93 for the second crop) was recorded under the highest level of nitrogen and

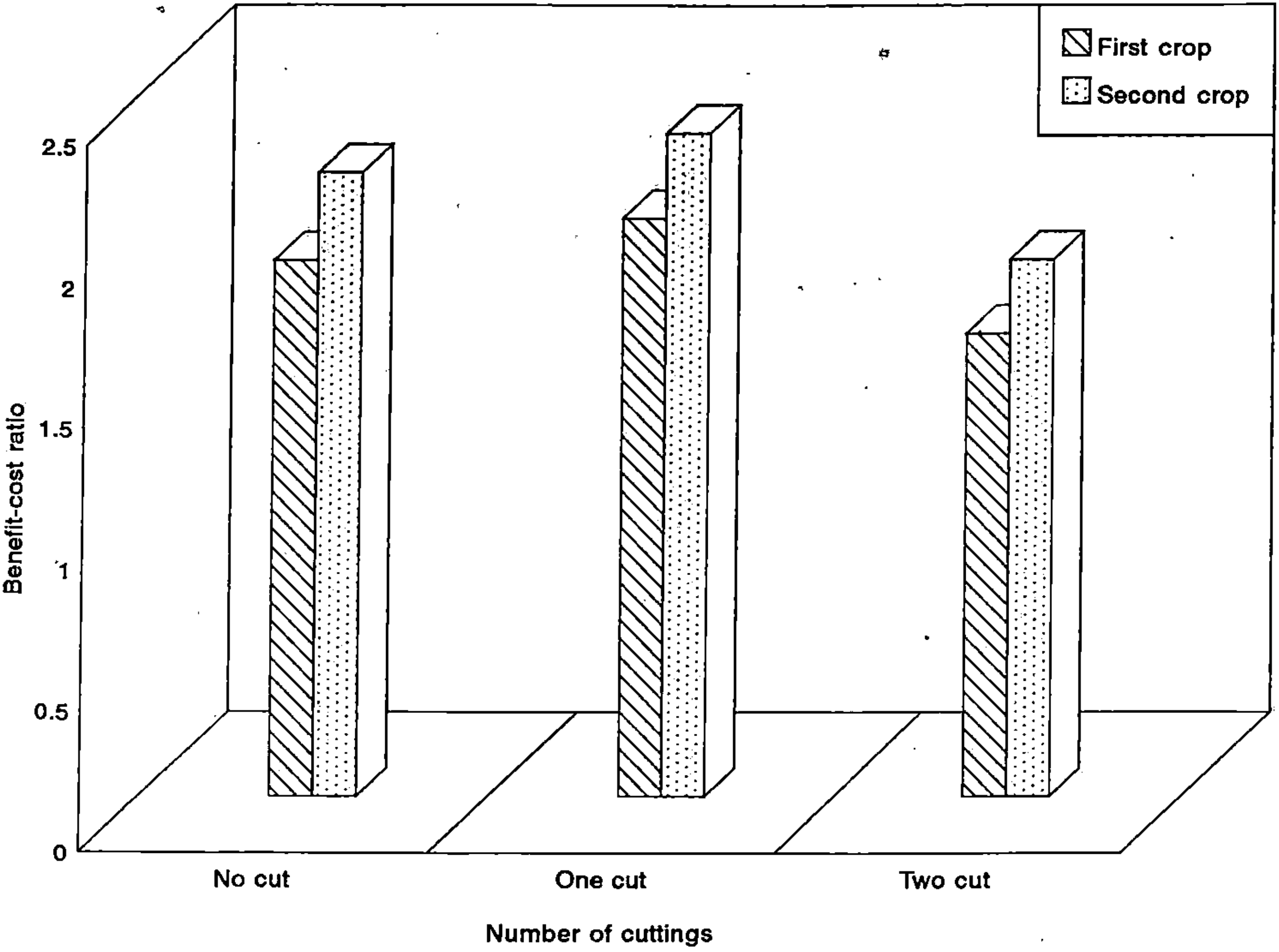

Fig.3. Influence of cuttings on benefit-cost ratio

potassium (N 150 kg ha^{-1} and K_2O 100 kg ha^{-1}) when one cutting was taken. Among the PK and cutting interactions, application of phosphorus and potassium at the highest levels (P_2O_5 100 kg ha^{-1} and K_2O 100 kg ha^{-1}) resulted in the highest benefit-cost ratio (2.22 for the first crop and 2.53 for the second crop).

The green yield and the seed yield and hence the benefit-cost ratio obtained in the second crop season (February, 1996 to June, 1996) was significantly higher than that obtained in the first crop season (October, 1995 to February, 1996). The temperature and humidity ranges were favourable for getting a warm humid climatic condition during the second crop season and such a condition is highly favourable for the best growth of amaranthus. Thus the more favourable climatic condition when compared to the first crop season might have contributed to the better performance of amaranth crop during the second crop season.

The results on the whole revealed that apart from inherent varietal characters, nutrient supply and its availability largely decide upon the green yield as well as the seed yield in amaranth seed crop. Besides, the frequency of clippings also decide the green yield and seed yield. The amaranth variety Arun used in the study found it as a highly fertilizer responsive (NPK 150:100:100 kg ha^{-1}) and a dual purpose amaranth variety. The study further points to the fact that for the seed crop it is better to take one vegetable harvest before leaving it for seed production. The quality of the greens were significantly altered by the application of NPK. Nitrogen and phosphorus application reduced the oxalate content whereas the potassium application increased the oxalate content. In the case of nitrate content, nitrogen and potassium application increased the nitrate content but the effect of phosphorus was found to be insignificant. The quality comparison of the two crops showed that the oxalate and nitrate accumulation in the second crop was higher than that of first crop. Fertilization and vegetable harvests did not affect seed quality in the study. Thus the present study implies that in order to get maximum net returns from amaranth seed crop it is better to take one vegetable harvest and then the crop should be left for seed production.

Further studies on varietal difference and seasonal influence on green yield and seed yield would be needed to throw more light on this aspect. Since the highest levels of NPK tried gave maximum yield in all the three types of cuttings it seems that the crop may respond to still higher levels of nutrients when more number of clippings are made. This can be another line for future work.

Summary

6. SUMMARY

The investigation on "Effect of NPK and frequency of cuttings on yield and quality in *Amaranthus tricolor* L." was conducted during October, 1995 to June, 1996 at the Vegetable Research Farm of the Department of Olericulture, College of Horticulture, Vellanikkara. The amaranth variety Arun was used for the study. The experiment was laid out in a $(3^3+1)3$ partially confounded factorial design with two replications. The results of the experiment are summarised below:

1. There was significant increase in plant height with increase in levels of NPK nutrients. But the extent of increase was more in the case of nitrogen when compared to phosphorus and potassium.

2. The green yield increased significantly with every increase in level of NPK nutrients. The highest green yield of 11.6 t/ha was obtained at N 150 kg ha^{-1} and P_2O_5 100 kg ha^{-1} (N_3P_3) for plants with one vegetable harvest (30 DAP). For plants with two vegetable harvests (30 DAP and 50 DAP) also the highest green yield was recorded under N 150 kg ha^{-1} and P_2O_5 100 kg ha^{-1}. The green yield at this fertilizer combination was 11.96 t/ha for the first harvest and 18.7 t/ha for the second harvest.

3. There was significant decrease in the oxalate content with the increase in application of nitrogen and phosphorus upto the highest level tried (N 150 kg ha^{-1}, P_2O_5 100 kg ha^{-1}). The potassium application increased the oxalate content significantly. The percentage of oxalate in greens changed from 6.79 at N_1 to 5.85 at N_3, 6.49 at P_1 to 6.15 at P_3 and 6.2 at K_1 to 6.44 at K_3 for plants

given one vegetable harvest. For plants given two vegetable harvests (30 DAP and 50 DAP), the percentage of oxalate changed from 6.79 at N_1 to 5.87 at N_3, 6.50 at P_1 to 6.16 at P_3 and 6.21 at K_1 to 6.45 at K_3 at first harvest. At second harvest, the changes in oxalate content was from 6.29 per cent at N_1 to 5.37 per cent at N_3, 5.96 per cent at P_1 to 5.71 per cent at P_3 and 5.75 per cent at K_1 to 5.95 per cent at K_3.

4. The nitrate accumulation was found increasing with the increase in levels of nitrogen. But nitrate accumulation was not significantly affected by different levels of phosphorus applied. In the case of potassium also there was significant increase in nitrate content though the extent of increase was less when compared to that of nitrogen application. For plants given one vegetable harvest, the nitrate content increased from 0.46 per cent at N_1 to 0.74 per cent at N_3 and 0.529 per cent at K_1 to 0.67 per cent at K_3. The content of nitrate increased from 0.47 per cent at N_1 to 0.73 per cent at N_3 and 0.53 per cent at K_1 to 0.66 per cent at K_3 at first harvest for plants given two vegetable harvests. At second harvest (50 DAP) the nitrate level increased from 0.39 per cent at N_1 to 0.65 per cent at N_3 and 0.46 per cent at K_1 to 0.58 per cent at K_3.

5. There was significant increase in seed yield due to increase in levels of NPK nutrients. The highest seed yields of 1538.1 kg ha^{-1} and 1462.43 kg ha^{-1} were obtained under N 150 kg ha^{-1} and P_2O_5 100 kg ha^{-1} (N_3P_3) for plants with no vegetable harvest and one vegetable harvest respectively. For plants with two vegetable harvests, the highest seed yield of 509 kg ha^{-1} was obtained under N 150 kg ha^{-1} and K_2O 100 kg ha^{-1} (N_3K_3).

6. Seed yield was altered by frequency of cuttings also. The highest seed yield of 1073 kg ha^{-1} was recorded by plants with no vegetable harvest. This was followed by plants with one vegetable harvest (1036.2 kg ha^{-1}). The lowest seed yield of 358.8 kg ha^{-1} was recorded by plants given two vegetable harvests.

7. Neither the NPK levels nor the number of cuttings had significant effect on 100 seed weight, seed germination and seedling vigour. The 100 seed weight recorded was 0.81 g. The germination percentage ranged from 70 to 72. The vigour index of seedlings ranged from 524 to 529.

8. Benefit-cost ratio was worked out and the optimum number of vegetable cuttings that can be taken so as to get maximum net returns from the seed crop was found to be one cutting. There was significant increase in benefit-cost ratio with increase in levels of the NPK. Plants from which one cutting was taken recorded the maximum benefit-cost ratio of 2.35. The highest benefit-cost ratio of 2.97 was obtained with one vegetable harvest under N 150 kg ha^{-1} and P_2O_5 100 kg ha^{-1} ($N_3P_3C_1$).

References

REFERENCES

Abdul-Baki, A.A. and Anderson, J.D. 1970. Viability and leaching of sugars from germinating barley crop. *Crop Sci.* 10:31-34

* Ackerman, H. and Gebauer, H. 1957. The toxicity of oxalate containing vegetables and feed plants. *Nahrung*. 1:278-285

* Agerton, B. and Martin, S. 1980. *Potassium for Agriculture*. Potash and Phosphate Institute, Ibadan, p.36

Ahmed, N. and Tanki, M.I. 1988. Effect of nitrogen and phosphorus on seed production of turnip (*Brassica rapa* L.). *Veg. Sci.* 15(1):1-7

Aworh, C.O., Hicks, J.R. and Minotti, P.L. 1979. Effect of plant maturity and nitrogen fertilization on nitrate accumulation and post harvest nitrite accumulation in fresh spinach. *J. Amer. Soc. hort. Sci.* 104:417-419

Baboo, R. and Sharma, R.K. 1995. Nutrient uptake and yield of fenugreek (*Trigonella foenum-graecum* L.) as affected by nitrogen, phosphorus and cutting management. *Veg. Sci.* 22(2):77-80

*Barker, A.V. and Maynard, D.N. 1971. Response of leafy vegetables to nitrogen fertilization. *Commun. Soil Sci. Plant Anal.*, 2:471-478

Barker, A.V., Peck, N.H. and Donald, G.E.M. 1971. Nitrate accumulation in vegetables. *Agron. J.* 63:126-129

Bartolini, J.S. and Hampton, J.G. 1989. Grain amaranth seed development, yield and quality. *Proceedings of the Annual Conference*. Agronomy Society, New Zealand, p.50-56

Campbell, T.A. and Abbott, J.A. 1982. Field evaluation of vegetable amaranth. *Hort. Sci.* 17(3):407-409

Cheeke, P.R. and Bronson, J. 1980. Feeding trials with amaranthus grain, forage and leaf protein concentrates. *Proceedings of the Second Amaranth Conference*. Rodale Press Inc., Emmaus, p.5-11

Commoner, B. 1970. *Global Effects of Environmental Pollution*. Springer-Verlag, New York, p.75-95

Custic, M., Poljak, M. and Cosic, T. 1994. Nitrate content in leafy vegetables as related to nitrogen fertilization in Croatia. *Acta Horticulturae* 371:407-412

* Deutsch, J.A. 1977. Genetic variation of yield and nutritional value in several *Amaranthus* species used as a leafy vegetable. Ph.D. thesis, Cornell University, Ithaca, New York

Devadas, V.S. 1982. Screening for non-bolting type of amaranthus suited for year round planting. M.Sc.(Hort.) thesis, Kerala Agricultural University, Thrissur

Devadas, V.S., Nair, M.V. and Peter, K.V. 1989. Genetic variability, correlation and path co-efficient analysis in vegetable amaranthus. *Amaranth News-letter* (2):7-9

Eheart, J.F. and Massey, P.H. 1962. Factors affecting the oxalate content of spinach. *J. Agric. Food. Chem.* 10:325-327

* Ehrendorfer, K. 1961. Oxalic acid in spinach. *Bodenkultur* 12:100-111

Enyi, B.A.C. 1965. Effect of age of seedlings, height and frequency of cutting on growth and yield of African spinach (*Amaranthus oleraceus*.) *Nigerian agric J.* 2:35-38

Grubben, G.J.H. 1976. *Cultivation of Amaranth as Leaf Vegetable*. Royal Tropical Institute, Amsterdam, p.92-93

* Grutz, W. 1956. The relationship between nutrient supply and oxalic acid formation in plants. *Landw. Forschung* 7:121-135

Gupta, K. and Wagle, D.S. 1988. Nutritional and antinutritional factors of green leafy vegetables. *J. Agric. Food Chem.* 36:472-474

Hackett, C. and Carolance, J. 1982. *Edible Horticultural Crops - Part I.* Academic Press, New York, p.25

Halfacre, R.G. and Barden, J.A. 1979. *Horticulture*. Mc Graw-Hill Book Company, New Delhi, p.304

Hauplti, H. and Jain, S.K. 1977. Evaluation of agronomic potential and genetic variation in amaranth collection. *Agronomy Abstracts* 58:485-488

Hauplti, H. and Jain, S.K. 1980. Genetic polymorphisms and yield components in a population of amaranth. *J. Herid.* 71(4):290-292

Hill, R.M. and Rawate, P.D. 1982. Evaluation of food potential, some toxicological aspects and preparation of a protein isolate from the aerial part of amaranth. *J. Agric. Food Chem.* 30(3):465-469

* Hilman, Y. and Abidin, Z. 1987. The effect of nitrogen fertilization on the growth and yield of four amaranthus cultivars. *Buletin Penelitian Hortikultura* 15(4):22-29

* Iengar, N.G.C. and Rao, Y.V.S. 1952. Green leafy vegetables as source of calcium. *Ann. Biochem. Exptl. Med.* 12:41-52

ISTA, 1985. International rules for seed testing. *Seed Sci. Technol.* 13(2):307-355

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall Inc., New Jersey, p.38-183

* James, L.F. 1968. Serum electrolyte acid base balance and enzyme changes in acute *Halogeton glomeratus* poisoning in sheep. *Can. J. Comp. Med.* 32:539-43

Jeghers, H. and Murphy, R. 1945. Practical aspects of oxalate metabolism. *New Eng. J. Med.* 233:208

Kamalanathan, S., Sundararajan, S., Thamburaj, S. and Shanmugam, A. 1973. CO.1 Amaranthus - a high yielding and delicious strain. *Madras agric. J.* **60**:355-358

Keskar, B.G., Bhore, D.P. and Maslekar, S.R. 1983. A note on effects of nitrogen on yield of Chaulai (*A. blitum). Haryana J. hort. Sci.*. 122(3):241-243

Kumar, P.B., Acharya, P.K., Dora, D.K. and Behera, T.K. 1994. Effect of graded levels of nitrogen and potassium on seed production of radish (*Raphanus sativus* L.) cv. Pusa Chetki. *Orissa J. Hort.* 22(1-2):36-39

Kwack, B.H. and Kang, H. 1985. Effects of specific light quality on seed germination of *Amaranthus hypochondriacus. Journal of the Korean Society for Horticultural Sciences* **26**(2):158-162

Makus, D.J. 1992. Fertility requirement of vegetable amaranth (*Amaranthus tricolor* L.) in an upland mineral soil of the mid-south. *Acta Horticulturae* (318):291-298

Mallika, V.K. 1987. Genome analysis in the genus *Amaranthus*. Ph.D.(Hort.) thesis, Kerala Agricultural University, Thrissur

Marderosian, A.D., Bentler, J., Pfendner, W., Chambers, J., Yoder, R., Weinsteiger, E. and Sheft, J. 1980. Nitrate and oxalate content of vegetable amaranth. *Proceedings of the Second Amaranthus Conference*. Rodale Press Inc., Emmaus, p.31-40

Maynard, D.N., Barker, A.V., Minotti, P.L. and Peck, N.H. 1976. Nitrate accumulation in vegetables. *Adv. Agron.* **28**:71-118

Meena, B.A., Umapathy, K.P., Pankaja, N. and Prakash, J. 1987. Soluble and insoluble oxalates in selected foods. *J. Food Sci. Technol.* 24(1):43-44

Minotti, P.L. and Stankey, D.L. 1973. Effect of environment and fertilizer on nitrate content of lettuce. *Hort. Science* **8**:33-34

Mohideen, M.K. and Muthukrishnan, C.R. 1980. Studies on correlation, multiple regression and path analysis as related to yield of vegetable amaranth (*A. tricolor*). *Proceedings of the Second Amaranth Conference.* Rodale Press, Emmaus, p.74-78

Mohideen, M.K. and Muthukrishnan, C.R. 1981. Studies on performance of amaranthus (*A. gangeticus* L.) at different stages of harvest. *South Indian Hort.* 29(2):104-109

Mohideen, M.K. and Rajagopal, A. 1974. Response of amaranthus to clipping. *Madras agric J.* 61:885-886

Mohideen, M.K. and Shanmugasubramanian, A. 1974. Correlation studies in amaranthus, *Amaranthus flavus* L. *South Indian Hort.* 22:132-133

* Mugerwa, J.S. and Bwabye, R. 1974. Yield, composition and *in vitro* digestibility of *Amaranthus hybridus* sub sp. *incurvatus*. *Trop. grasslands* 8(1):49-53

Mugerwa, J.S. and Stafford, W. 1976. Effect of feeding oxalate rich amaranthus on ovine serum calcium and oxalate levels. *E. Afric. Agrl. For. J.* 42(1):71-75

National Institute of Nutrition, 1991. *Nutritive Value of Indian Foods*. Siddamsetty Press, Hyderabad. p.48

Ndyanab, W.K. 1974. Oxalate content of some commonly grazed pasture forages of Lango and Acholi districts of Uganda. *E. Afric. Agrl. For. J.* 39:215

Nehru, S.M. and Thampi, A.M. 1987. *An innovative approach in the extension of vegetable production technology at Palappur.* College of Agriculture, Kerala Agricultural University, Vellayani, Trivandrum, p.20-30

Olufolagi, A.O. and Tayo, A.O. 1989. Performance of four morphotypes of *Amaranthus cruentus* L. under two harvesting methods. *Tropical Agriculture* 66(3):273-276

Panda, J.M., Sahu, S.K. and Nayak, J.K. 1991. Effect of nitrogen, phosphorus and potash on growth, yield and quality of kosala (*Amaranthus tricolor*). *Orissa J. Hort.* 19(1-2):64-68

Panse, V.G. and Sukhatme, P.V. 1978. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi, p.154-168

Pareek, S.K. and Gupta, R. 1981. Effect of fertilizer application on seed yield and diosgenin content in fenugreek. *Indian J. agric. Sci.* 50(10):746-749

Peek, N.H., Barker, A.V., Mac Donald, G.E. and Shallenberger, R.S. 1971. Nitrate accumulation in vegetables in response to variable nitrogen fertilization. *Agron. J.* 63:130-132

* Pingle, U. and Ramasastri, B.V. 1976. Absorption of calcium from a leafy vegetable rich in oxalates. *Br. J. Nutr.* 39:119

Purushothaman, V. 1978. Effect of nitrogen sources and levels on yields of some leafy vegetables in Malaysia. *Malaysian agric. J.* 51(4):366-374

Rajagopal, A., Muthukrishnan, C.R., Mohideen, M.K. and Syed, S. 1977. CO.2 amaranthus - an early vigorous variety. *South Indian Hort.* 25:102-106

Ramachandra, H.A. 1978. Effect of different levels of nitrogen and phosphorus on growth, yield and quality attributes to amaranthus (*Amaranthus gangeticus* Linn. cv. A-25). *Mysore J. agric. Sci.* 12(3):526-527

Ramachandra, H.A. and Thimmaraju, K.R. 1983. Effect of different levels of nitrogen and phosphorus on growth components and yield of amaranthus (*A. tricolor* L.). cv. A-25. *Mysore Journal of Agricultural Sciences* 17(2):158-164

Reyes, F.G., Santos, A.T. and Zapata, V.M.C. 1988. Effect of high nitrogen doses and plant density on the yield *Amaranthus hypochondriacus* (L.). *Amaranth Newsletter* (1):6-9

* Sadik, S. 1971. Oxalate contents of some leafy vegetables. *Paper Sem. Agric. Res.* Institute of Tropical Agriculture, Ibadan

Salini, S.S. 1975. Effect of cuttings on the seed yield of methi (*Trigonella foenum graecum*). *Haryana J. Hort. Sci.* 4(1-2):82-85

Sarah, T.G. 1986. Studies on some important yield contributing and nutritive characters in leaf amaranth (*Amaranthus* spp.). Ph.D. thesis, IARI, New Delhi

Schmidt, D.R. 1971. Comparative yields and composition of eight tropical leafy vegetables grown at two soil fertility levels. *Agron. J.* 63:546-550

Schmidt, D.R., Mac Donald, H.A. and Brockman, F.E. 1971. Oxalate and nitrate content of four tropical leafy vegetables grown at two soil fertility levels. *Agron. J.* 63(4):559-561

Schmidth, D.R. 1986. Response of grain amaranth and sorghum to variable fertilization. *Amaranth Newsletter* (3):10-13

Sidhu, S. and Arora, S.K. 1980. Grow amaranth as greens. *Intens. Agric.* 17(11):29-30

Singh, P.P. 1973. The oxalic acid content of Indian foods. *Qual. Plant Mater. Veg.* 22(3-4):335-347

*Singh, P.P. 1974. Influence of light intensity, fertilizers and salinity on oxalate and mineral concentration of two vegetables - *Chenopodium album* and *C. amaranthicolor. Qual. Plant. Pl. Fds. Hum. Nutr.* 24(1-2):115-125

Singh, P.P. and Sharma, D.C. 1968. Significance of some leaf flours in animal nutrition. The effect of feeding the diets containing Kulfa leaf flour. *Indian Med. Gaz.* 7(12):28-33

Singh, P.P., Sharma, D.C. and Mongia, S.P. 1971. Clinical aspects of oxalate metabolism. *Indian Med. Gaz.* 11(8):29-36

Singh, P.P. and Sur, B.K. 1962. Unknown bond oxalate in the leaves of Bathua (*Chenopodium album* L.). *Curr. Sci.* 31:333-334

Singh, U.C., Sundararajan, S. and Veeraraghavathatham, D. 1985. Effect of split application of nitrogen on growth and yield of amaranthus (*Amaranthus tristis* L.) CO.3. *South Indian Hort.* 33(2):100-102

Singh, U.C., Sundararajan, S. and Veeraraghavathatham, D. 1985. Effect of split application of nitrogen on certain qualitative characters of amaranthus (*A. tristis* L.) cv. CO.3. *South Indian Hort.* 33(4):230-233

Sinha, S.K., Singh, J.N., Jha, B.N. and Mishra, M. 1985. Influence of nitrogen and cutting on seed production of palak (*Beta vulgaris* L. var. *bengalensis). Seed Research* 13(2):73-77

Sreevastava, S.K. and Krishnan, P.S. 1959. Oxalate content of plant tissues. *J. Sci. Industr. Res.* 18:146-168

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

Subhan, 1989. Effect of dosage and application time of nitrogen fertilizer on growth and yield of amaranth (*Amaranthus tricolor* L.). *Buletin Penelitian Hortikultura* 17(3):31-40

Sulekha, G.R. 1980. Studies on the effect of plant population density and age at transplanting on the growth, frequency of harvest and total vegetable yield in amaranthus (*Amaranthus gangeticus* L.). M.Sc.(Hort.) thesis, College of Agriculture, KAU, Vellayani, Trivandrum

Talapatra, S.K., Ray, S.C. and Sen, K.C. 1948. Calcium assimilation in ruminents on oxalate rich diet. *J. Agric. Sci.* 36:163

Thamburaj, S., Suresh, J. and Seralathan, A. 1994. Screening amaranthus germplasm for oxalic acid content. *South Indian Hort.* 42(1):22-25

Thomas, T. and Krishnamurthy, H.K. 1988. Grain amaranthus, a savior to cereal based diets. *Amaranth Newsletter* (4):12-15

Traynor, J. 1980. *Ideas in Soil and Plant Nutrition*. Kovak Books, Bakersfield, p.120

Trevino, I.C. and Murray, G.A. 1975. Nitrate accumulation in vegetables. *Crop Sci.* 15:500-502

Van Eijnatten, C.L.M. 1970. Freedom from higher campaign. Report to the Government of Nigeria. Home gardens for improved human nutrition. Royal Tropical Institute, Mauritskade, Amsterdam

Varalakshmi, B. and Reddy, V.V.P. 1994. Variability, heritability and correlation studies in vegetable amaranthus. *South Indian Hort.* 42(6):361-364

Verma, A.N., Srivastava, D.C. and Sharma, R.K. 1969. Effect of nitrogen supply on growth,. yield, ascorbic acid and oxalic acid content in spinach (*Spinacea oleracea* L.). *Plant Sci.* 1:189-191

Vijayakumar, M., Shanmugavelu, K.C. and Kader Mohideen, M. 1982. Studies on growth and development of certain types of amaranthus (*Amaranthus* sp. L.). *South Indian Hort.* 30(4):256-261

Vityakon, P. and Standal, B.R. 1989. Oxalate in vegetable amaranth-forms, contents and their possible implication for human health. *J. Sci. Food Agric.* 48(4):469-474

Watnabe, F.S. and Olsen, S.R. 1965. Test of an ascorbc acid method for determining phosphorus in water and $NaHCO_3$ extract from soil. *Proc. Soil Sci. Soc. Am.* 29:677-678

Watts, P.S. 1959. Effects of oxalic acid ingestion by sheep. *J. agric. Sci.* 52;250

* Originals not seen

Appendices

Appendix I. Chemical characteristics of the soil in the experimental site

Characteristics	Content in soil (per cent)
Available nitrogen	0.0112
Available phosphorus	0.0004
Available potassium	0.0048
pH	5.1

Appendix II. Weather data at monthly intervals during the experimental period
(October 1995 - June 1996)

Months	Air temperature °C			Mean RH (%)	Rainfall (mm)	Rainy days	Evaporation (mm)	Mean sunshine hours
	Mean max.	Mean min.	Mean					
1995								
October	33.2	23.2	28.2	78	100.4	8	113.8	8.3
November	31.3	22.5	26.9	80	88.4	5	89.1	6.5
December	32.5	21.3	26.9	57	-	-	195.9	10.3
1996								
January	33.1	22.4	27.8	53	-	-	208.6	9.4
February	34.7	23.4	29.1	53	-	-	200.9	9.9
March	36.4	24.3	30.4	60	-	-	219.2	9.3
April	34.6	25.0	29.8	73	152.0	7	157.0	8.3
May	32.8	25.2	29.0	77	95.4	4	135.0	7.7
June	30.5	23.8	27.2	85	400.3	16	103.4	4.7

Appendix III. Analysis of variance for height of plants with no vegetable harvest

Source	D.F.	Mean squares for height of plants (cm)					
		First crop			Second crop		
		30DAP	50 DAP	Seed harvest stage	30 DAP	50 DAP	Seed harvest stage
Block	5	480.75**	239.469**	421.46**	312.65**	244.788**	645.219**
N	2	921.91**	3822.92**	3024.297**	2578.375**	4969.83**	4432.97**
P	2	24.262**	152.84**	84.75**	100.414**	239.86**	191.726**
NP	4	14.19**	36.789**	58.26**	49.164**	72.79**	60.914**
K	2	22.609**	62.547**	62.343**	70.133**	99.91**	86.89**
NK	4	10.453**	12.375**	18.609**	12.468*	13.24**	19.878**
PK	4	4.244*	12.117**	12.163*	12.306*	17.296**	16.484**
NPK	2	4.137*	4.4405**	2.5156	9.945	8.921*	8.281
NPK^2	2	1.6992	0.9536	9.960	4.113	2.022	9.094
NP^2K	2	0.9514	1.0552	2.0859	2.367	1.125	1.406
NP^2K^2	2	1.0154	0.9922	3.1641	0.918	2.625	1.063
Control Vs rest	1	3380.08**	9267.78**	9705.06**	5900.41**	9523.06**	9034.28**
Error	27	1.0608	1.0279	3.0028	3.0425	2.6486	3.4761

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix IV. Analysis of variance for height of plants with one vegetable harvest

Source	D.F.	Mean squares for height of plants (cm)					
		First crop			Second crop		
		First harvest stage	50 DAP	Seed harvest stage	First harvest stage	50 DAP	Seed harvest stage
Block	5	417.30**	89.355**	110.075**	387.47**	365.938**	240.525**
N	2	1128.91**	1651.449**	3179.156**	2075.77**	2304.09**	3175.52**
P	2	16.42**	62.37**	102.078**	92.06**	86.03**	104.266**
NP	4	4.257*	4.187*	12.653*	17.389**	32.488**	19.766**
K	2	18.40**	31.535**	57.805**	32.547**	46.938**	61.797**
NK	4	4.311*	4.245*	11.445*	10.222*	15.539**	12.237*
PK	4	3.364*	3.949*	9.969*	10.131*	11.139**	11.726*
NPK	2	1.3711	0.9539	8.1211	5.0313	9.148*	6.1609
NPK^2	2	0.7656	1.3711	8.2813	1.1016	3.238	2.125
NP^2K	2	0.446	0.1132	1.1563	0.1383	2.229	0.9406
NP^2K^2	2	0.3757	0.1992	1.1660	1.0468	1.078	1.0703
Control Vs rest	1	3038.83**	3543.56**	6414.24**	4725.93**	3818.72**	5585.88**
Error	27	1.0537	1.0457	3.1116	2.502	2.153	3.010

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix V. Analysis of variance for height of plants with two vegetable harvests

Source	D.F.	Mean squares for height of plants (cm)					
		First crop			Second crop		
		I harvest stage	II harvest stage	Seed harvest	I harvest stage	II harvest stage	Seed harvest
Block	5	350.237**	177.359**	217.85**	258.242**	378.347**	212.284**
N	2	1013.027**	1999.52**	1855.76**	1780.05**	1912.84**	2542.399**
P	2	24.97**	52.71**	38.594**	72.824**	64.602**	60.141**
NP	4	11.686**	12.369**	10.145**	22.404**	13.839**	15.258**
K	2	31.089**	39.55**	30.174**	38.289**	38.352**	39.797**
NK	4	6.1113**	7.0645**	6.029**	10.003**	6.3477**	7.929*
PK	4	3.639*	6.2031**	4.348**	8.252*	4.5892**	6.796*
NPK	2	1.2266	3.602*	2.125	6.114	3.0535*	2.0938
NPK^2	2	1.4102	0.0237	0.0527	1.1719	0.011	1.0781
NP^2K	2	0.2617	0.1306	0.977	2.4199	0.1296	0.1152
NP^2K^2	2	0.0547	0.156	0.1564	1.664	0.1211	0.078
Control Vs rest	1	3026.7**	3476.9**	2550.42**	4822.89**	3573.31**	3895.16**
Error	27	0.8878	0.7934	1.0532	2.014	0.8981	1.9443

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix VI. Analysis of variance for green yield of plants with one vegetable harvest

Source	D.F.	Mean squares for weight of greens					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Block	5	128.94**	110301.6**	4446555.3**	376.39**	128740.8**	5189889.2**
N	2	1298.69**	1209026.0**	48739102.4**	3072.23**	2454500.0**	98947522.2**
P	2	25.52**	20672.0**	833344.13**	140.91**	46976.8**	1893761.6**
NP	4	7.83**	4450.47*	179410.46*	47.18**	9763.0**	393572.89*
K	2	19.49**	21360.0**	861079.27**	85.98**	43532.0**	1754892.5**
NP	4	4.29**	4427.25*	178474.4*	22.77**	9971.0**	401957.9**
PK	4	3.97**	4337.58*	174859.56*	12.59**	8967.0*	361484.0*
NPK	2	2.48*	2320.6	93549.65	7.87*	4756.0	191727.2
NPK^2	2	0.59	3211.8	129476.33	3.69	2280.0	91912.9
NP^2K	2	1.13	560.0	22575.11	1.38	2030.0	81834.8
NP^2K^2	2	0.32	372.0	14996.32	1.05	1044.0	42086.5
Control Vs rest	1	2058.43**	1930456.0**	77821893.6**	3684.1**	3033576.0**	122291639.0**
Error	27	0.7077	1085.48	43757.15	1.621	2381.45	95999.87

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix VII. Analysis of variance for green yield at first harvest of plants given two vegetable harvests

Source	D.F.	Mean squares for weight of greens					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Block	5	130.91**	69292.8**	2793379.9**	155.2**	81281.6**	3276680.8**
N	2	1377.25**	1462754.0**	58967563.2**	2839.04**	2839184.0**	114455172.8**
P	2	34.09**	42640.0**	1718933.5**	75.04**	55888.0**	2252996.2**
NP	4	6.21*	8174.39**	329531.7**	39.95**	9912.0**	399579.48**
K	2	32.81**	36312.0**	1463834.8**	47.55**	48676.0**	1962261.0**
NK	4	6.75**	8564.0**	355238.0**	7.92**	7941.8**	320155.4**
PK	4	6.44**	7472.0*	301216.5*	4.62**	7067.0**	284889.9**
NPK	2	3.37	4128.0	166410.8	3.77	5136.4	207062.2
NPK^2	2	3.85	5165.0	208215.1	1.145	2064.0	83205.4
NP^2K	2	0.482	1293.0	52124.3	1.49	1084.0	43699.0
NP^2K^2	2	0.584	1228.0	49504.0	1.06	1168.0	47085.0
Control Vs rest	1	1838.9**	2509004.0**	101144725.5**	3663.43**	3445200.0**	138885314.0**
Error	27	1.5642	1977.84	79729.55	1.3882	1715.292	69146.09

* Significant at 5 per cent level

* Significant at 1 per cent level

Appendix VIII. Analysis of variance for green yield at second harvest of plants given two vegetable harvests

Source	D.F.	Mean squares for weight of greens					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Block	5	529.3**	436275.2**	17587431.3**	782.24**	622444.0**	25092398.2**
N	2	10301.8**	6522280.0**	262930716.9**	12906.94**	9460664.0**	381384909.6**
P	2	274.6**	160216.0**	6458739.5**	290.94**	88440.0**	3566255.2**
NP	4	86.46**	90988.0**	3667971.9**	138.43**	14573.0**	587477.0*
K	2	133.4**	92120.0**	3713605.9**	210.48**	86888.0**	3502689.9**
NK	4	31.01**	17466.0**	704101.6**	43.82**	15875.0**	639964.1**
PK	4	18.74**	12562.0*	506408.1*	33.84**	15019.0**	605456.4**
NPK	2	12.99**	8496.0	392496.7	25.53*	9776.0	394097.0
NPK^2	2	5.59	5752.0	231878.7	17.92	8424.0	339594.2
NP^2K	2	2.36	3693.0	148874.8	5.8	1744.0	70305.3
NP^2K^2	2	1.45	4101.0	165322.4	5.28	1348.0	54341.5
Control Vs rest	1	10697.8**	7058020.0**	284527842.8**	14363.52**	9889680.0**	398679702.9**
Error	27	3.8671	4039.54	162840.26	7.4657	3644.387	146910.96

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix IX. Analysis of variance for oxalate content

Source	D.F.	Mean squares for oxalate content in per cent					
		Plants with one vegetable harvest		Plants with two vegetable harvests			
		First crop	Second crop	First crop		Second crop	
				First harvest	Second harvest	First harvest	Second harvest
Block	5	0.0397**	0.0400**	0.0395**	0.0267**	0.0391**	0.031**
N	2	4.1342**	3.9790**	4.0249**	3.7965**	3.8009**	3.7932**
P	2	0.5593**	0.5215**	0.526**	0.3400**	0.5509**	0.2927**
NP	4	0.046**	0.073**	0.043**	0.0068**	0.095**	0.04**
K	2	0.2578**	0.2683**	0.2377**	0.1701**	0.2606**	0.2313**
NK	4	0.018**	0.024**	0.034**	0.0038**	0.02**	0.03**
PK	4	0.017**	0.0181**	0.017**	0.0031**	0.03**	0.015**
NPK	2	0.006*	0.0045	0.004	0.0029**	0.008*	0.002
NPK^2	2	0.0032	0.0021	0.0024	0.0019*	0.0001	0.001
NP^2K	2	0.002	0.0017	0.0018	0.0001	0.0001	0.001
NP^2K^2	2	0.0007	0.0046	0.0021	0.0004	0.0019	0.003
Control VS rest	1	5.9387**	5.797**	5.8425**	4.3186**	5.3737**	4.1625**
Error	27	0.001634	0.001925	0.001494	0.00051	0.00166	0.001406

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix X. Analysis of variance for nitrate content

Source	D.F.	Mean squares for nitrate content in per cent					
		Plant with one vegetable harvest		Plant with two vegetable harvests			
		First crop	Second crop	First crop		Second crop	
				First harvest	Second harvest	First harvest	Second harvest
Block	5	$4.738x10^{-03}$**	$2.342x10^{-03}$**	$2.26x10^{-03}$**	$1.906x10^{-03}$**	$2.375x10^{-03}$**	$1.502x10^{-03}$**
N	2	0.3034**	0.3353**	0.2932**	0.31609**	0.2935**	0.3068**
P	2	$1.168x10^{-04}$	$9.53x10^{-05}$	$2.432x10^{-05}$	$6.1989x10^{-06}$	$9.059x10^{-05}$	$3.481x10^{-05}$
NP	4	$4.720x10^{-05}$	$1.326x10^{-04}$	$4.053x10^{-05}$	$8.774x10^{-05}$	$3.462x10^{-05}$	$8.845x10^{-05}$
K	2	$8.006x10^{-02}$**	$8.423x10^{-02}$**	$7.456x10^{-02}$**	$6.426x10^{-02}$**	$8.012x10^{-02}$**	$6.242x10^{-02}$**
NK	4	$3.886x10^{-3}$**	$6.294x10^{-03}$**	$2.337x10^{-03}$**	$1.959x10^{-03}$**	$2.241x10^{-03}$**	$1.6046x10^{-03}$**
PK	4	$5.817x10^{-06}$	$3.2377x10^{-06}$	$1.104x10^{-06}$	$3.839x10^{-05}$	$7.105x10^{-06}$	$1.025x10^{-05}$
NPK	2	$2.193x10^{-05}$	$6.67x10^{-06}$	$6.432x10^{-05}$	$2.069x10^{-05}$	$1.430x10^{-05}$	$1.345x10^{-05}$
NPK^2	2	$4.768x10^{-06}$	$4.435x10^{-05}$	$2.962x10^{-05}$	$1.678x10^{-06}$	$1.335x10^{-05}$	$6.818x10^{-06}$
NP^2K	2	$2.598x10^{-05}$	$6.675x10^{-06}$	$7.796x10^{-05}$	$4.792x10^{-05}$	$2.623x10^{-05}$	$1.144x10^{-05}$
NP^2K^2	2	$6.676x10^{-06}$	$1.4782x10^{-05}$	$3.815x10^{-06}$	$1.098x10^{-05}$	$2.479x10^{-05}$	$2.598x10^{-06}$
Control Vs rest	1	0.5725**	0.63174**	0.5789**	0.4128**	0.6455**	0.4172**
Error	27	$1.9647x10^{-04}$	$1.2828x10^{-04}$	$8.507x10^{-05}$	$4.816x10^{-05}$	$1.027x10^{-04}$	$5.5437x10^{-05}$

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XI. Analysis of variance for seed yield of plants with no vegetable harvest

Source	D.F.	Mean squares for seed yield					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Block	5	0.4203**	1006.98**	40594.08**	1.666**	2716.3**	109501.4**
N	2	73.82**	63188.13**	2547284.13**	78.534**	67643.75**	2726902.2**
P	2	1.742**	1531.13**	61723.98**	1.81**	1454.125**	58619.7**
NP	4	0.609**	139.45*	5621.61*	0.647**	304.91*	12291.75*
K	2	1.909**	1213.69**	48927.12**	1.346**	1335.31**	53830.0**
NK	4	0.411**	280.95**	11325.85**	0.21*	283.78*	11440.0*
PK	4	0.303**	192.52**	7761.0**	0.1734*	220.72*	8897.8*
NPK	2	0.1874*	85.19	3434.24	0.0457	121.13	4883.1
NPK^2	2	0.0844	40.25	1622.59	0.0301	58.9	2374.4
NP^2K	2	0.0135	17.33	698.62	0.0425	43.12	1738.3
NP^2K^2	2	0.0003	10.72	432.15	0.0033	29.78	1200.5
Control Vs rest	1	74**	57052.0**	2299920.16**	80.32**	83464.8**	3364691.4**
Error	27	0.0524	34.014	1371.44	0.0512	76.25	3074.6

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XII. Analysis of variance for seed yield of plants with one vegetable harvest

Source	D.F.	Mean squares for seed yield					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Block	5	0.617**	797.98**	32168.7**	1.16**	2782.0**	112149.9**
N	2	64.31**	59552.25**	2400712.0**	71.62**	62851.25**	2533703.6**
P	2	2.104**	1264.44**	50973.0**	1.972**	1021.44**	41177.0**
NP	4	0.4204**	132.93**	5358.77**	0.36**	243.625**	9821.18**
K	2	1.129**	899.88**	36276.6**	1.448**	928.13**	37415.4**
NK	4	0.141*	207.22**	8353.6**	0.342*	138.87*	5598.2*
PK	4	0.123*	132.24**	5331.0**	0.235*	103.84*	4186.07*
NPK	2	0.007	77.59	3127.9	0.0849	82.69	3333.5
NPK^2	2	0.0452	109.34*	4407.8*	0.043	54.94	2214.8
NP^2K	2	0.0031	35.94	1448.8	0.047	20.47	825.2
NP^2K^2	2	0.0009	10.24	413.21	0.0498	11.38	458.8
Control Vs rest	1	64.55**	60187.82**	2426333.5**	65.24**	77125.25**	3109127.1**
Error	27	0.0344	32.162	1296.89	0.0855	34.27	1381.84

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XIII. Analysis of variance for seed yield of plants with two vegetable harvests

Source	D.F.	Mean squares for seed yield					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Block	5	0.2142**	76.177**	3070.9**	0.2965**	285.43**	11506.6**
N	2	21.35**	6869.06**	276910.4**	24.04**	7616.8**	307053.8**
P	2	0.284**	102.04**	4113.5**	0.1422**	156.17**	6295.6**
NP	4	0.0869*	23.07*	930.0*	0.0696**	18.62**	750.62**
K	2	0.3785**	82.72**	3334.7**	0.555**	98.98**	3909.5**
NK	4	0.0766*	15.67*	631.7*	0.0462*	29.99**	1209.0**
PK	4	0.0596*	15.47*	623.6*	0.0457*	17.78*	716.8*
NPK	2	0.0057	10.97	442.2	0.0126	9.008	363.14
NPK^2	2	0.0038	4.25	171.33	0.0072	5.086	205.03
NP^2K	2	0.0033	1.77	71.4	0.0005	5.48	220.9
NP^2K^2	2	0.0052	1.11	44.75	0.0057	2.53	102.0
Control Vs rest	1	12.21**	5920.26**	238661.7**	10.668**	8504.53**	342840.6**
Error	27	0.0215	5.6455	227.585	0.01649	4.4345	178.745

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XIV. Analysis of variance for seed yield

Source	D.F.	Mean squares for seed yield					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
Block	5	1.171**	1771.13**	71399.03**	2.68**	4783.4**	192831.8**
N	2	151.1**	118580.43**	4780297.3**	165.83**	136111.8**	5487034.2**
P	2	3.73**	2677.6**	107941.29**	3.81**	2431.73**	98029.6**
NP	4	1.02**	275.45**	11104.13**	0.993**	527.16**	21251.24**
K	2	3.22**	2010.62**	81053.5**	3.31**	2160.42**	87092.4**
NK	4	0.588**	452.87**	18296.73**	0.522*	422.64**	17037.8*
PK	4	0.453**	315.23**	12707.8**	0.41*	308.34*	12430.0*
NPK	2	0.182	157.73	6358.5	0.099	202.81	8175.82
NPK^2	2	0.094	138.54	5584.9	0.072	118.93	4794.4
NP^2K	2	0.016	47.04	1896.31	0.088	57.02	2298.6
NP^2K^2	2	0.006	19.06	768.36	0.049	31.423	1266.75
Control Vs rest	1	140.8**	112050.7**	4517066.3**	146.23**	149094.5**	6010401.9**
Error	27	0.0963	61.845	2493.14	0.133	107.96	4352.16

Contd.

Appendix XIV. Continued

Source	D.F.	Mean squares for seed yield					
		First crop			Second crop		
		Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)	Yield/plant (g)	Yield/plot (g)	Yield/ha (kg)
C	2	98.13**	159422.45**	6426749.4**	102.11**	216497.12**	8727583.45**
NC	2	12.64**	9114.23**	367419.2**	12.89**	9514.74**	383564.9**
PC	4	4.11**	1253.84**	50545.7**	4.45**	1883.55**	55774.64**
NPC	8	0.89**	632.35**	25491.7**	1.11**	811.05**	32695.62**
KC	4	0.95**	288.17**	11616.9**	1.02**	398.95**	16082.75**
NKC	8	0.124**	108.17**	4382.4**	0.243**	175.06**	7057.14**
PKC	8	0.078*	49.96*	2014.0*	0.114*	78.19*	3152.1*
NPKC	16	0.007	12.52	504.72	0.036	22.66	913.49
Between control	2	0.159**	1112.0**	44827.7**	0.215**	1505.39**	60686.3**
Error	64	0.031	18.505	745.987	0.0429	30.471	1228.368

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XV. Analysis of variance for seed quality of first crop

Source	D.F.	Mean squares for weight of 100 seeds (g)		
		Plants with no vegetable harvest	Plants with one vegetable harvest	Plants with two vegetable harvest
Block	5	1.25169×10^{-07}	6.437302×10^{-07}	1.078844×10^{-06}
N	2	9.38581×10^{-07}	9.23872×10^{-07}	3.874302×10^{-07}
P	2	7.45058×10^{-08}	2.98023×10^{-07}	7.152558×10^{-07}
NP	4	3.002584×10^{-07}	4.097819×10^{-07}	2.011657×10^{-07}
K	2	8.49366×10^{-07}	3.57627×10^{-07}	1.788139×10^{-07}
NK	4	6.10947×10^{-07}	1.624227×10^{-07}	9.611249×10^{-07}
PK	4	2.17719×10^{-07}	2.682209×10^{-07}	2.30968×10^{-07}
NPK	2	3.68575×10^{-07}	2.384186×10^{-07}	2.086263×10^{-07}
NPK^2	2	3.42726×10^{-07}	5.811453×10^{-07}	2.384186×10^{-07}
NP^2K	2	1.341105×10^{-07}	7.674098×10^{-07}	7.003546×10^{-07}
NP^2K^2	2	6.03497×10^{-07}	9.313226×10^{-07}	5.960465×10^{-07}
Control Vs rest	1	2.47359×10^{-07}	3.874302×10^{-07}	1.400709×10^{-06}
Error	27	4.155768×10^{-07}	7.571998×10^{-07}	8.23427×10^{-07}

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XVI. Analysis of variance for seed quality of second crop

Source	D.F.	Mean squares for weight of 100 seeds (g)		
		Plants with no vegetable harvest	Plants with one vegetable harvest	Plants with two vegetable harvest
Block	5	8.58307×10^{-07}	2.92063×10^{-07}	3.87430×10^{-07}
N	2	4.47035×10^{-07}	2.235174×10^{-07}	9.2387×10^{-07}
P	2	5.662444×10^{-07}	1.23679×10^{-06}	1.26659×10^{-06}
NP	4	1.04308×10^{-07}	1.10268×10^{-06}	7.301569×10^{-07}
K	2	1.04310×10^{-07}	7.89762×10^{-07}	5.960465×10^{-07}
NK	4	9.234872×10^{-07}	7.52508×10^{-07}	8.19563×10^{-07}
PK	4	1.347091×10^{-06}	4.02331×10^{-07}	1.393259×10^{-06}
NPK	2	4.32134×10^{-07}	2.08616×10^{-07}	3.427267×10^{-07}
NPK^2	2	1.16229×10^{-06}	1.04308×10^{-07}	1.13408×10^{-07}
NP^2K	2	7.89762×10^{-07}	1.49102×10^{-07}	2.913178×10^{-07}
NP^2K^2	2	6.01624×10^{-07}	3.27826×10^{-07}	4.470349×10^{-07}
Control Vs rest	1	3.27825×10^{-07}	2.98023×10^{-07}	6.55651×10^{-07}
Error	27	6.92076×10^{-07}	8.653711×10^{-07}	6.14259×10^{-07}

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XVII. Analysis of variance for seed quality

Source	D.F.	Mean squares for 100 seeds (g) First crop	Second crop
Block	5	8.58302×10^{-07}	7.31124×10^{-07}
N	2	7.54928×10^{-07}	4.23581×10^{-07}
P	2	2.52327×10^{-07}	1.021392×10^{-06}
NP	4	3.01657×10^{-07}	9.466113×10^{-07}
K	2	2.788139×10^{-07}	2.99718×10^{-07}
NK	4	5.142279×10^{-07}	7.27321×10^{-07}
PK	4	2.324581×10^{-07}	2.23526×10^{-07}
NPK	2	2.292206×10^{-07}	2.39188×10^{-07}
NPK^2	2	2.861023×10^{-07}	1.13427×10^{-07}
NP^2K	2	3.344098×10^{-07}	3.034117×10^{-07}
NP^2K^2	2	4.013226×10^{-07}	5.92236×10^{-07}
Control Vs rest	1	5.00679×10^{-07}	3.87528×10^{-07}
Error	27	6.17143×10^{-07}	6.85621×10^{-07}
C	2	6.7742×10^{-07}	3.47152×10^{-07}
NC	4	8.2261×10^{-07}	1.34964×10^{-07}
PC	4	8.4964×10^{-07}	1.28512×10^{-07}
NPC	8	1.2642×10^{-07}	0.33273×10^{-07}
KC	4	0.9228×10^{-07}	0.52024×10^{-07}
NKC	8	1.90453×10^{-07}	1.42746×10^{-07}
PKC	8	1.42286×10^{-07}	1.13714×10^{-07}
NPKC	16	0.7033×10^{-07}	0.7562×10^{-07}
Between controls	2	1.0000×10^{-07}	1.0000×10^{-07}
Error	64	5.99948×10^{-07}	5.21034×10^{-07}

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix XVIII. Analysis of variance for mean germination per cent of seeds

Source	D.F.	Mean squares for mean germination per cent of seeds					
		Plants with no vegetable harvest		Plants with one vegetable harvest		Plants with two vegetable harvest	
		First crop	Second crop	First crop	Second crop	First crop	Second crop
Block	5	0.86875	0.375	0.2875	0.8	0.2375	1.2375
N	2	1.0625	0.84375	0.5156	0.3906	0.0625	0.9063
P	2	0.6406	2.375	0.3281	0.1718	0.7813	0.9471
NP	4	0.2398	0.4375	0.414	0.8437	1.3594	0.9063
K	2	0.8281	0.4063	0.3582	0.0468	0.5781	0.6406
NK	4	1.0546	0.3359	0.4297	0.3828	0.8984	0.5703
PK	4	0.2656	0.6094	2.3125	1.9921	0.3906	1.625
NPK	2	0.9679	0.0469	0.0625	0.43725	0.2812	0.2344
NPK^2	2	0.1969	2.0625	1.1093	1.0625	0.578	0.1719
NP^2K	2	0.25656	1.8672	0.8984	0.25	0.2352	0.2656
NP^2K^2	2	0.9531	0.8672	0.6953	1.3672	0.2812	0.2336
Control Vs rest	1	0.25	0.1979	0.0937	0.9375	0.1563	0.0625
Error	27	0.7465	1.1377	0.9931	1.1314	1.1366	0.6603

Appendix XIX. Analysis of variance for mean germination per cent

Source	D.F.	Mean squares for germination per cent	
		First crop	Second crop
Block	5	0.5500	0.2666
N	2	0.8750	0.6142
P	2	0.0833	0.4166
Np	4	1.0000	0.4791
K	2	0.6667	0.9583
NK	4	1.0833	0.2291
PK	4	0.3958	0.1458
NPK	2	1.3750	0.2396
NPK^2	2	1.2083	1.0989
NP^2K	2	0.0416	0.6875
NP^2K^2	2	0.6687	0.8284
Control Vs rest	1	0.1166	0.3333
Error	27	0.9520	0.8842
C	2	0.816	0.076
NC	4	0.379	1.057
PC	4	0.860	1.041
NPC	8	1.372	0.821
KC	4	1.127	0.110
NKC	8	0.658	0.571
PKC	8	1.264	1.076
NPKC	16	0.653	0.793
Between controls	2	0.042	0.292
Error	64	0.9865	0.9241

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix XX. Analysis of variance for vigour index of seedlings

Source	D.F.	Mean squares for vigour index of seedlings					
		Plants with no vegetable harvest		Plants with one vegetable harvest		Plants with two vegetable harvest	
		First crop	Second crop	First crop	Second crop	First crop	Second crop
Block	5	44.6	4	5.8	11.4	31	31.8
N	2	12	16	10	5	3.5	10
P	2	16.5	5	14	17.5	19.5	19
NP	4	46.5	5	4	6.25	31.25	43.25
K	2	6.5	3.5	110.5	21	15	93.5
NK	4	53.5	21.75	60.5	34	52.5	14
PK	4	11.25	16.25	2.75	13.25	43	11.5
NPK	2	45	7	1.5	47	23	13.5
NPK^2	2	59	9.55	28	30	10.5	4.75
NP^2K	2	26	10.8	21.5	18	74.5	19
NP^2K^2	2	26	20	61	45.25	24	90.25
Control Vs rest	1	21	7	29	37	22	2
Error	27	32.44	43.7	42.59	50.98	39.85	28.52

Appendix XXI. Analysis of variance for vigour index of seedlings

Source	D.F.	Mean squares for vigour index of seedlings	
		Frst crop	Second crop
Block	5	30.93	16.000
N	2	13.3333	2.6667
P	2	2.6666	24.00
NP	4	33.333	14.667
K	2	13.333	18.6667
NK	4	5.333	17.333
PK	4	5.333	13.333
NPK	2	18.667	16.000
NPK^2	2	5.333	21.333
NP^2K	2	10.667	21.333
NP^2K^2	2	16	64.000
Control Vs rest	1	20.001	26.667
Error	27	38.716	46.62
C	2	57.428	47.857
NC	4	7.334	14.530
PC	4	23.692	8.696
NPC	8	23.463	19.102
KC	4	60.594	54.604
NKC	8	40.132	26.541
PKC	8	25.345	13.196
NPKC	16	32.760	44.724
Between controls	2	36.489	15.381
Error	64	37.8712	36.7622

Appendix XXII. Analysis of variance for benefit-cost ratio

Source	D.F.	Mean squares for benefit-cost ratio					
		Plants with no vegetable harvest		Plants with one vegetable harvest		Plants with two vegetable harvest	
		First crop	Second crop	First crop	Second crop	First crop	Second crop
Block	5	0.21933**	0.22565**	0.22355**	0.20789**	6.8069×10^{-02}**	0.1170**
N	2	4.50037**	4.4970**	4.3973**	4.41303**	3.3803**	3.6456**
P	2	0.20615**	0.2027**	0.1969**	0.1961**	0.16201**	0.1559**
NP	4	6.4849×10^{-02}**	6.7302×10^{-02}**	5.8664×10^{-02}**	8.7738×10^{-02}**	4.9907×10^{-02}**	7.6408×10^{-02}**
K	2	0.10821**	0.10893**	0.10376**	0.1116**	9.8358×10^{-02}**	0.1058**
NK	4	1.9455×10^{-02}**	1.6801×10^{-02}**	2.28×10^{-02}*	1.5078×10^{-02}**	1.96511×10^{-02}**	1.4959×10^{-02}**
PK	4	1.7014×10^{-20}**	1.6296×10^{-02}**	1.4583×10^{-02}**	2.222×10^{-02}*	1.102×10^{-02}*	9.7322×10^{-03}*
NPK	2	1.6022×10^{-02}*	1.089×10^{-02}	3.9405×10^{-03}	4.2724×10^{-03}	5.3405×10^{-03}	4.4250×10^{-03}
NPK^2	2	8.1553×10^{-03}	1.334×10^{-02}*	2.8228×10^{-03}	2.3651×10^{-03}	2.4414×10^{-03}	3.3569×10^{-03}
NP^2K	2	2.1362×10^{-03}	4.577×10^{-03}	6.86412×10^{-04}	1.4725×10^{-03}	1.4763×10^{-03}	1.1825×10^{-03}
NP^2K^2	2	1.602×10^{-03}	2.0599×10^{-04}	1.0299×10^{-04}	1.007×10^{-04}	1.8566×10^{-04}	1.2359×10^{-03}
Control Vs rest	1	4.334**	4.448**	4.313**	4.8053**	2.7288**	2.97496**
Error	27	3.5369×10^{-03}	3.9612×10^{-03}	3.65025×10^{-03}	5.700×10^{-03}	2.7474×10^{-03}	3.6397×10^{-03}

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix XXIII. Analysis of variance for benefit cost ratio

Source	D.F.	Mean squares for benefit cost ratio	
		First crop	Second crop
Block	5	0.4888**	0.5399**
N	2	12.256**	12.5249**
P	2	0.5625**	0.5723**
NP	4	0.15238**	0.20145**
K	2	0.29989**	0.3258**
NK	4	5.1184×10^{-02}**	5.355×10^{-02}**
PK	4	3.9967×10^{-02}*	4.624×10^{-02}*
NPK	2	2.0303×10^{-02}	1.857×10^{-02}
NPK^2	2	1.1419×10^{-02}	1.806×10^{-02}
NP^2K	2	4.1004×10^{-03}	7.232×10^{-03}
NP^2K^2	2	1.4905×10^{-03}	1.541×10^{-03}
Control Vs rest	1	10.273**	11.217**
Error	27	9.734×10^{-03}	1.22×10^{-02}
C	2	2.3125**	2.93**
nC	4	0.2725**	0.31575**
PC	4	0.1001**	0.1524**
NPC	8	8.75×10^{-02}**	9.179×10^{-02}**
KC	4	5.752×10^{-02}**	5.997×10^{-02}**
NKC	8	1.564×10^{-02}**	1.8238×10^{-02}**
PKC	8	6.633×10^{-03}*	8.244×10^{-03}*
NPKC	16	2.7536×10^{-03}	3.0994×10^{-03}
Between controls	2	8.1×10^{-02}	9.9×10^{-02}
Error	64	3.1273×10^{-03}	3.749×10^{-03}

* Significant at 5 per cent level

** Significant at 1 per cent level

EFFECT OF NPK AND FREQUENCY OF CUTTINGS ON YIELD AND QUALITY IN *Amaranthus tricolor* L.

By

DEEPA SUKUMAR

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF HORTICULTURE
Vellanikkara - Thrissur

1997

ABSTRACT

An experiment entitled "Effect of NPK and frequency of cuttings on yield and quality in *Amaranthus tricolor* L." was conducted at the Department of Olericulture, College of Horticulture, Vellanikkara during the period from October, 1995 to June, 1996 to study the effect of NPK and frequency of cuttings on yield and quality in amaranth variety Arun. The experiment was laid out in a $(3^3 + 1)3$ partially confounded factorial design with two replications.

The NPK levels (N 50, 100 and 150 kg ha^{-1}; P 50, 75 and 100 kg ha^{-1}; K 50, 75 and 100 kg ha^{-1}) and cuttings (C_0 - no vegetable harvest, C_1 - one vegetable harvest and C_2 - two vegetable harvests) had a significant impact on various growth, yield and quality characters. The plant height and the green yield increased with increasing levels of NPK. But the extent of increase was more with respect to nitrogen application.

Application of nitrogen and phosphorus brought out significant decrease in the oxalate content (from 7.3% - 4.84%) upto the highest level tried (N 150 kg ha^{-1} and P 100 kg ha^{-1}). But, potassium application increased the oxalate content significantly (from 5.7% to 6.44%). A clear cut increase in nitrate accumulation (from 0.17% to 0.74%) was noticed with increasing levels of nitrogen. Nitrate accumulation was not significantly affected by phosphorus levels. In the case of potassium also there was a significant increase in nitrate content (from 0.17% to 0.67%) though the extent of increase was less when compared to that of nitrogen application.

The seed yield increased significantly due to increasing levels of all the three nutrients and plants with no vegetable harvest recorded the highest seed yield (1073 kg ha^{-1}). Neither the nutrients nor the cuttings had significant effect on seed germination and seedling vigour.

There was a significant increase in benefit-cost ratio with increasing levels of all the three nutrients. Plants from which one cutting was taken recorded the maximum benefit-cost ratio (2.35). So the optimum number of vegetable cuttings that can be taken from a seed crop so as to get maximum net return was found to be one. After taking one vegetable harvest (30 DAP) the crop should be left for seed production.