PHD

The effects of mineral nutrition on seed yield and quality of cauliflower (Brassica oleracea var. botrytis L.) and mustard broad leaf (Brassica juncea (L.) Czern and Coss).

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THE EFFECTS OF MINERAL NUTRITION ON SEED YIELD AND QUALITY OF CAULIFLOWER (BRASSICA OLERACEA VAR. BOTRYTIS L.) AND MUSTARD BROAD LEAF (BRASSICA JUNCEA (L.) CZERN AND COSS).

Submitted by

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SUMMARY

The effect of mother plant nutrition on the seed yield and quality of cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. Snowball and mustard broad leaf (*Brassica juncea* Czern and Coss.) cv. Miike Giant were investigated under the field and glasshouse conditions.

Increase in the levels of nitrogen (equivalent to 50 to 150 kg/ha), phosphorus (equivalent to 0 to 150 kg/ha) and potassium (equivalent to 50 to 100 kg/ha) all applied as base dressing did not affect the seed yield of cauliflower under glasshouse conditions. In field conditions, total nitrogen (equivalent to 50 kg/ha to 350 kg/ha) applied in three split doses and phosphorus (equivalent to 50 kg/ha to 200 kg/ha) had not significantly increased the seed yield of cauliflower. In a container grown crop of mustard broad leaf nitrogen equivalent to up to 300 kg/ha increased the seed yield but the application of phosphorus had no effect.

The percentage distribution of graded seeds produced was not affected by mother plant nutrition in cauliflower or mustard broad leaf.

Increase in the nitrogen level to the mother plant did not improve the seed quality of cauliflower as assessed by field emergence tests, controlled deterioration test and electrical conductivity test, but in mustard broad leaf, N_2

produced seeds which showed poor performance in seed quality tests. A further increase in nitrogen to level N_3 did not significantly affect seed quality.

Phosphorus application generally increased germination percentage, 100 seed weight, field emergence percentage and germination percentage after controlled deterioration and decreased the electrical conductivity reading and mean time to emergence in cauliflower seeds. Addition of phosphorus had no effect on seed quality of mustard broad leaf.

An increase in potassium application had generally no effect on the seed quality. There was a slight decrease in 100 seed weight and germination percentage with increase in potassium level.

NP, NK, PK and/or NPK interactions effect was noticed in most seed quality tests. Generally higher levels of phosphorus with lower levels of potassium and medium level of nitrogen produced seeds which showed comparatively higher vigour in electrical conductivity, controlled deterioration, rate of emergence and field emergence tests.

The small seeds (grade C below 1.7 mm in cauliflower and grade B, below 1.4 mm in mustard broad leaf) were consistently showing low vigour in the tests used. The differences in seed quality tests between grade A (above 2.00 mm), B (between 1.7 and 2.00 mm) or D (ungraded) seeds in cauliflower were not significant.

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INTRODUCTION

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A. General Introduction

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most important vegetables in Britain (Anon. 1981). It is grown in many parts of the world, especially in the temperate regions. It is also grown in the cool season in the warmer regions. It is usually regarded by consumers as a luxury vegetable. Except in West Germany and the Netherlands, where some 100 hectares are produced as a protected crop, cauliflower is usually gorwn in the open.

The Mediterranean region is regarded as the main centre of origin of cauliflowers. Secondary centres of development of the cauliflower were central and north west Europe, including Germany, Belgium and Denmark, and the maritime regions of north west Europe, including parts of France, Britain and the Netherlands. From about the 16th century the annual or the summer types of cauliflower were bred in the former area, including the Danish, Alpha, Erfurter (Snowball) and the Mechelese types. From the 18th century onwards the maritime regions of north west Europe, with its milder winters, supported the development of biennial forms. This led to the formation of late autumn and winter types of cauliflower.

During the 18th and 19th centuries, the cauliflower was introduced into India and from there it spread to Nepal. In the Indian subcontinent, re-combination of annual and biennial types took place and new types were developed which were suited to that part of the subcontinent (Anon. 1981).

Important cauliflower growing countries, in order of acreage, are given in Table 1.

Table 1. Production of cauliflower

Country	Area (1000 ha.)	Yield (kg/ha)	Production (1000 Metric Tonnes)
India	90F	7,333	660F
China	62F	12,358	760F
France	40F	12,283	495
Italy	27	28,238	545
U.S.A.	17	11,337	195
U.K.	15	21,233	319
Poland	11F	13,084	140
Spain	9	22,556	203

F = F.A.O. estimate

(Source: Food and Agriculture Organisation Production Year Book, Vol. 34, 1980).

It is seen from Table 1 that the U.K. produces approximately 15,000 hectares annually. The value is estimated to be about £40 millions (Anon. 1981). In 1979, 7% of the total area of vegetable production in England was under cauliflower. The area of cauliflower in England and Wales was about 8,000 hectares in 1938 and rose to 12,600 ha. in 1962 (Nieuwhof, 1969) and to 16,200 ha. in 1979 (Anon. 1981).

Britain imports cauliflower mainly during December to April from France, Italy and Spain. During this period the cauliflower production in Britain is affected by adverse weather. In 1979, about 19000 tonnes of cauliflower was imported. During peak production period, Britain exports cauliflower to other European countries. In 1979, about 265 tonnes were exported from Britain (Anon, 1981).

Cauliflower is a relatively difficult crop to produce and production area is therefore restricted to specific favourable localities. Southern England and certain coastal areas are the main producing region in the U.K.

Based on the maturity time, the cauliflower can be grouped into:

a. Early cultivars

b. Late summer and autumn cultivars

c. Winter cultivars.

a. Early cultivars

These cultivars are harvested in spring or early summer. The main cultivars in this group include Erfurter (Snowball), Alpha, Mechelese types.

b. Late summer and autumn cultivars

Depending upon planting time and the cultivar, the harvest of this group of cauliflower starts from summer and continues until late autumn. The main cultivars include Australian, Italian and Florablanca types.

c. <u>Winter cultivars</u>

The winter cultivars are harvested from winter to spring, the early types in this group being less winter hardy than the late types. The main cultivars include Roscoff, Walchern types.

In cauliflower production, temperature plays an important role. In different types of cauliflower, the temperature requirement for transition to generative phase and also before and after generative phase is important. In the temperate zones, the annual cultivars of cauliflower, after having formed a number of leaves, pass into generative stage. In these cultivars, the maxiumum temperature for head formation is between 20°C and 25°C, optimum being 17°C. At higher temperatures, the plant may remain vegetative. The autumn types of cauliflower may also need similar maximum temperature as summer types but as the varieties gradually change into winter types, they become generative only if the temperature is below 10°C (Nieuwhof, 1969). Sadik (1967) found a distinctive cold requirement for curd formation and flowering. For an early cultivar such as Snowball M, it formed head with or without cold treatment but for flowering cold treatment was needed. But for later cultivars such as 'February-Early March' cold treatment was needed for both curd formation and flowering. Cold treatment is effective if the plant has reached "juvenile stage" (Aamlid, 1952; Skapski and Oyer, 1964). Salter and James (1974) also found the effect of cold treatment on the maturity of autumn cauliflower heads.

In Nepal, cauliflower is grown during winter months in mid-hills and plain areas but in the regions above 3000 m, it is grown during summer and autumn.

B. Seed Situation in Nepal

Due to altitude ranging from 50 m above mean sea level to about 8840 m, there are several agro-climatic regions in Nepal which are broadly dividied into three regions (Pandey, 1979):

a. Plain or terai

b. Mid-hills

c. Inner Himalayan valley

The altitude in the plain area ranges from 50 to 600 m and the mean temperature from 7°C to 24°C during winter (November-January) to 24°C - 34°C during summer (April - August). The summer rainfall varies from 1800 mm in the east to 900 mm in the west. The western terai receives brief westerly showers during the winter. This belt does not experience frost during winter. The main vegetable seeds produced are tomato, chillies *(Capsicum frutescens* L.), eggplant, okra, beans *(Phaseolus vulgaris* L.), onion, cucurbits such as cucumber *(Cucumis sativus* L.), pumpkin *(Cucurbita maxima* Duch.) sponge gourd *(Luffa cylindrica* Roem), bottlegourd *(Lagenaria ciceraria* (Mol.). sandl.) bitter gourd *(Momordica charantia* L.) and peas *(Pisum sativum* L.).

In the mid-hills the altitude ranges from 600 - 2000 m above mean sea level. In this region the mean temperature ranges from 2^{o} - 17^{o}C during winter to 20^{o} - 27^{o}C during summer. Occasional frosts are experienced during the winter months. Summer rains are heavy but decreases westwards. The western half, however, receives some westerly rain in winter. The main vegetable seeds produced are radish, mustard broadleaf *(Brassica juncea* (L). Czern and Coss), cauliflower, turnip, cress *(Lepidium sativum* L.) pea *(Pisum sativum* L.) bean *(Phaseolus vulgaris* L.), spinach *(spinacea oleracea* L.) tomato and pepper *(Capsicum annum* L.)

The inner Himalayan valley ranges from 2000 to 4500 m above mean sea level and has a mean temperature range of 0^{o} - 10^{o}C during winter to 12^{o} - 21^{o}C during summer. This region experiences snowfall and at times heavy frosts during the winter months. The main vegetable seeds produced are cabbage, turnip, carrot, mustard broadleaf, pea and cress.

The whole of Nepal comes under the monsoon belt experiencing the monsoon rains during June to September and comparatively dry spell during the rest of the year. There are some pocket areas which are protected by mountain ranges and have very low rainfall even during the monsoon. Some regions especially mid-hills receive hailstorms during spring and autumn.

In 1975, the total area under vegetable cultivation was 82,000 ha. and by the end of five year plan (1979 - 80), a projected area of 120,000ha. was estimated to have been brought under cultivation (Pandey, 1979).

Due to lack of authoritative data it is difficult to assess the exact vegetable seed requirements of Nepal. However, the following targets were fixed by the Vegetable Development Division (V.D.D.) of the Department of Agriculture for the different vegetable seeds for 1979 - 80.

1. Breeders seed - 150 kg
2. Foundation or basic seed - 1500 kg
3. Certified or commercial seed - 29,000 kg

Production target for cauliflower and mustard broadleaf seeds for 1979 - 80 were fixed as follows:

cauliflower - 940 kg

Mustard broadleaf - 1045 kg

(V.D.D. Programme, 1979 - 80).

Some farmers produce their own seed from a small number of plants selected for this purpose. All of the mustard broadleaf and about 75% of cauliflower seed requirements are produced in the country. The seeds are produced either at Government horticultural farms or by trained farmers. The remaining seeds of cauliflower are imported from India, or elsewhere, such as Holland and Japan.

The Vegetable Development Division states in their 1979 - 80 programme:

1. In order to improve the quality of the vegetable seeds, priority will be given for the production of breeds and foundation seeds at different government farms and

horticultural centres.

2. Emphasis will be placed on producing commercial seeds in the private sector

(V.D.D. Programme, 1979 - 80).

The cultural value of cauliflower cultivars is influenced by the environemnt under which it grows. A cultivar may be entirely adapted to the conditions prevailing in a certain locality and to the methods of culture which are applied there; however, when grown in another region the same cultivar may give unsatisfactory results - even under seemingly similar growing conditions (Nieuwhof, 1969). The wide variations in agro-climatic regions of Nepal make it difficult for the local main cultivar (Kathmandu Local) and a few imported cultivars (e.g. Dania, Snowball) to grow successfully in different regions. The imported cultivars are relatively unreliable especially when they are grown at different altitudes. Farmers also need more proven cultivars of cauliflower for continuity of production. So it has become very important to identify the right cultivar for different regions and for specific production periods. This problem is not so serious with mustard broadleaf of which leaves are eaten and the local types have adapted to the conditions.

Some regions in Nepal especially towards northwest get low rainfall and have cool dry weather with plenty of sunshine during seed ripening period. Emphasis is being given to grow seeds in these regions. Seeds produced here are of good quality and they will not only supply the country's needs, but they can be exported to neighbouring countries such as Bangladesh, Sri Lanka, Thailand, Burma and India. Some vegetables which have a vernalization requirement for flower initiation, the seeds of such vegetables can be produced in the mid-hill or inner Himalayan regions and exported to those countries where such seeds cannot be produced. Therefore improvement in technique of seed production including identification of appropriate cultivars, strict roguing or selecting and producing them in disease free areas are necessary.

C. The Importance of Seed Quality

There is an increasing interest in seed quality in the seed industry. Seed quality is a concept made up of different attributes. These attributes are of interest to different segments of the industry - to producer, the processor, the warehouseman, the merchant, the farmer, the certification authority and to the government or agency responsible for seed control (ISTA, 1976). Seed quality information will enable the farmers to make economic decisions regarding the cost of seeds, earliness and rate of sowing and the anticipated uniformity of the stand. Low quality seed may lead to fewer seedlings than expected or to a stand of uneven-sized seedlings and its influence may persist to affect the final crop yield and size distribution (Perry, 1982). The seed is the starting point in the production of a crop, other investments or inputs such as fertilizers, irrigation and crop protection chemicals are superimposed. It, therefore, follows that the higher the quality of seed the less risk there would be in other investments during the production of a crop (George, 1980).

The seed costs for most field vegetable crops are as low as 1% of the grower's production costs, it is ridiculous to buy cheaper seed if even a small part of high quality is sacrificed. Even a 1% gain in crop yield will pay for all seed costs (Harrington, 1971). Seedmen believe that seed quality information will aid them in monitoring seed quality during processing. Seed quality tests might reveal where loss in the seed viability occurs during operations such as harvesting, cleaning, drying, storing and packaging and may pinpoint adverse practices which could subsequently be improved (McDonald, 1980). According to Thomson (1979), the high quality seed lot should have the following attributes:

1. it should be of high analytical, species and cultivar purity;
2. it should be free from weed seeds;
3. it should be of high germination capacity and vigour;
4. it should be uniform and large;
5. it should be free from seed borne diseases;

and 6. it should be of low moisture content.

Analytical purity indicates how much of the material in the bag is of the type named on the label. Impurities are separated from the pure seed. The impurities of the seed may be other than crop species, weed seeds and inert materials such as broken seeds, chaff, pieces of plant debris and soil particles. Analytical purity is the basic component of seed quality.

The seed should be free from noxious weeds. Specific weeds which are not present in a given locality could be introduced through contaminated lots. Usually weed seeds are expressed as number found in the weight of seed examined.

The seed must be entire, undamaged and well developed. It must have all the morphological characteristics which identify its species and/or its cultivar. Sometimes the seed lot is graded to give better stand and performance in the field.

The seed should not carry seed borne diseases. They should be, preferably, produced in a disease free, uncontaminated and healthy environment.

The moisture content of the seed has a direct bearing on its keeping quality. It is the key factor in determining whether or not seed will retain its germination from harvest to sowing time. The seed lot should have low moisture content and packed in a container where the seeds do not absorb atmospheric moisture.

The seeds should be viable and should have high potential germination. Germination capacity of a sample from a seed lot, is so far the best indication of its ability to emerge in the field.

However, the germination conditions in the field are seldom, if ever, optimal. Many seeds which germinate under optimal conditions fail to emerge when the conditions are not optimal. The vigour of the seed indicates its ability to emerge under sub-optimal conditions. In recent years, emphasis is being given to this attribute of seed quality, the seed vigour.

REVIEW OF LITERATURE

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1. Seed Vigour

a). Concept of seed vigour

The concept of seed vigour has received a lot of attention in recent years. It is important to have a very good understanding of concept of vigour when direct precision sowing is replacing traditional cultivation methods and specific plant populations are required to achieve maximum yield. The following concepts have emerged which clarify the meaning of vigour in terms of seed, seedling and plant performance (Copland, 1976):

1. Rate of germination;
2. Uniformity of germination and plant development;
3. Ability to emerge through crusted soil;
4. Germination and seedling emergence from cold, wet pathogen-infested soil;
5. Normal seedling morphological development;
6. Crop yield;

and 7. Storability under optimum or adverse conditions.

A.O.S.A. (Association of Official Seed Analysis) vigour test subcommittee (McDonald, 1980) proposed the following definition of seed vigour:

"Seed vigour comprises those seed properties which determine the potential for rapid uniform emergence and development of normal seedling under wide range of field conditions". This definition focusses on what seed vigour *does* and is, therefore, considered to be an "operational" definition. After more than 25 years of deliberations the ISTA (International Seed Testing Association) vigour test committee has come to the following broad acceptable definition of seed vigour (Perry, 1978a):

"Seed vigour is the sum total of those properties of seed which determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence."

Seeds which perform well are termed "high vigour seeds" while those which perform poorly are called "low vigour seeds" (Perry, 1978a). Seeds show many variable properties when germinating and the definition goes on to describe four broad areas where they may be observed:

1) biochemical processes and reactions during germination, such as enzyme reactions and respiratory activities;
2) rate and uniformity of seed germination and seedling growth;
3) rate and uniformity of seedling emergence and growth in the field;
4) emergence ability of seedling under unfavourable environmental conditions.

In addition to these properties, it is also recognized that the effects of seed vigour may persist to influence mature plant growth, crop uniformity and yield. The vigour test committee also mentions that vigour cannot be quantified because it is a concept and only specific components can be expressed numerically e.g. rate of seedling growth, percentage field emergence.

b) Need of seed vigour test

The laboratory germination tests may not always correlate well with field emergence. The value of correlation coefficient between germination and emergence has been found to decline as the conditions become suboptimal and emergence fell. With cruciferous crops, there are variable reports of the relationship between germination and field establishment. Stahl (1931, 1933, 1936) examined turnip, radish, cabbage and cauliflower seed and demonstrated correlation coefficient of in excess of 0.90 for all of them. However, most of Stahl's results were obtained in a very good soil conditions of temperature and moisture levels. George and Atwood (1982) also got correlation of 0.95 between germination and emergence of cabbage when they grew the seeds in a glasshouse in trays using field soils. Here again moisture and temperature were optimal. But Richardson (1970) states that when the seeds were sown directly in the field in the normal sowing time the coefficient of 0.52 was obtained with cabbage and savoy seeds, although the rape, kale and borecale group was better with coefficient of 0.82. Hogarty (1974) stated that germination was not a reliable predictor for field emergence in calabrese and in leek. Bedford and Mackay (1973), illustrated the interaction between establishment and environment in their trials with several lots of onion and carrot seed. No correlation between germination and emergence was found when 12 seed lot were sown deeply and when the conditions were more favourable, significant correlation was obtained in two trials with several lots of onion seeds. Poor correlation between germination and field emergence has been reported in beans (Mathews and Bradnock, 1967), carrot (Hegarty, 1971), Peas (Baylis *et al.* 1943; Clark and Little, 1955; Mathew and Bradnock, 1967; Perry, 1967), onion (Clark, 1944), spinach (Clark and Kline, 1967), barley (Perry, 1980a).

Therefore, to correlate well between germination and emergence especially at suboptimal conditions vigour tests are required to differentiate between high and low vigour seeds. Under these conditions, high vigour seeds are more reliable and less sensitive to the vagaries of soil conditions than low vigour seeds (Perry, 1973, 1980a, 1980b).

c) Effects of seed vigour

Seed vigour is a major contributing factor which determines early seedling survival, stand establishment and, ultimately, whether or not a particular crop achieves its potential yield (Cantliffe,1981). Pollock and Roos (1972) pointed out the effects of vigour are concern to the growers. They mentioned in their review that vigour can express itself in seed germination (rate of germination, growth rate), in uniformity of performance, in plant growth and crop yield. The main effects of seed vigour is upon the ability of the seed to produce autotrophic seedling in the field. Soil conditions strongly influence the percentage of seedling emerging from the seed lot and the maximum possible, which would be equal to the number of normal seedlings produced in the laboratory test, may occur when the soil conditions are optimal (Perry, 1972). Seed with high vigour will generally give more rapid and uniform field emergence than seed with low level of vigour. Under poor seed bed conditions, seeds with high vigour may give a high percentage seedling emergence as well. However, under ideal field conditions germination performance of low and high vigour seed may not differ much (Brocklehurst, 1978).

The influence of high vigour seed may persist throughout the life of the plant and may affect the plant growth and final yield. Funk *et al.* (1962) found that in maize plants produced from weak seeds, as indicated by vigour tests, were low in emergence, smaller in seedling stage and had lower yield than plants from 'strong' (high vigour) seeds. Chen *et al.* (1972) obtained high, medium and low vigour seeds of radish, squash and turnip through artificial accelerated ageing. They found that growth and development were significantly affected by vigour levels of seed and it was much more pronounced in root yield of radish and turnip than top yield (leaf weight). Fleming (1966) comparing hybrid seed lots produced by different growers, found differences in yield between lots with the same laboratory germination but with differences in seed vigour. Similar results have been recorded with peas by Perry (1969) and with tomatoes by Clark and Kline (1965). Perry (1969) recorded yield reduction of 16.5% and 18% from low vigour pea seed lots compared with high vigour lots of the same cultivar grown at the same plant population in the field. Lange (1965) working with radish reported that plants from poor quality seed matured later and produced smaller roots than those from good quality seeds and equal size. Abdalla and Roberts (1969) exposed bean and pea seeds to high temperature and moisture to reduce their vigour to low levels. A study of the growth of the plants from these seeds showed that growth increases were dependent on quantity of activiity photosynthesizing plant tissue present, and that the early growth of roots and shoots was decreased but during the later stage of growth the difference in the plant were lost and there was no significant effect in the final yield. But if the seed deterioration during storage caused loss of viability below 50%, they produced small, slow growing seedling and the plants never compensated and yielded as much as ones from non-deteriorated seeds. Perry (1980a) deteriorated barley seed of high moisture percentage and temperature and found that vigorous seed had 94.8 - 77.5% emergence irrespective of soil environment while deteriorated seeds had 77% emergence in normal bed to 15.5% emergence in wet bed earlier in the season. The total grain yield at high population were similar regardless of initial seed quality but at lower densities, the yields from the plants established from deteriorated seeds were significantly less than those from control seed (with high vigour). Carvalho (1978) has found that high vigour seeds of peanut had a marked effect on rate and total seedling emergence in the earlier part of growth (up to 30 days after planting), but later on there was vigour and space interaction which resulted in a similar dry matter content after 60 days. However, on area basis, vigour had significant influence on the yield of peanut pods.

2. Causes of low seed vigour

The vigour test committee of ISTA mentions the following factors which can affect the vigour of seeds (Perry, 1978a):

1. Genetic constitution;
2. Environment and nutrition of mother plant;
3. Stage of maturity at harvest;
4. Seed size, weight or specific gravity;
5. Mechanical integrity;
6. Deterioration and ageing;
7. Pathogen

The causes of seed vigour may also be divided into two distinct groups: (Perry, 1978b):

1. Intrinsic variation due to genotype
2. Variation induced by external environment interacting upon the genotype.

A. Genetic constitution

The genotype determines the maximum possible seed vigour (Perry, 1978b). The differences in vigour between different species and cultivars are due to genotype effect. The effect of genetic control on seed and seedling vigour may be clearly illustrated by the higher seedling vigour of hybrid and polyploid plants over inbred and deploid plants of the same species. For example, hybrid seeds of barley have been found to germinate faster, grow faster and exhibit higher respiration rate than either parent (McDaniel, 1969). Seed coat may be controlled by genotype. Hard seed in soyabean (Potts *et al.*, 1978) has been suggested as a mechanism against conditions prevalent during delayed harvest. Seeds with soft seed coat are more liable to loss of vigour due to rain or other adverse conditions.

The genetically controlled variation in seed production and performance could also be linked in brassicas (Hodgkin, 1980). He stated that variation in seed-production characters would affect environment of the developing seed and thus could influence performance characters. In addition, genetic control of characters such as seed weight could affect both quality and quantity of the seeds produced.

B. Environment and seed vigour

The environmental factors such as water availability, temperature and nutrients, which affect the development of seeds will also affect the seed's vigour. The environment may also modify the seed vigour during maturation of seed on the mother plant, during harvest and during handling and storage. These environmental factors acting either separately or together may result in seed immaturity, variation in size, mechanical damage, deterioration in storage or invasion by pathogen (Perry, 1978b). The environmental factors which affect seed production can also affect the subsequent seed performance of a crop. Thus, seed production levels of *Brassica oleracea* crops can be reduced by attacks of *Alternaria,* a fungus which has been reported to reduce subsequent seed germination levels (Niuewhof, 1969). Low humidity, minimal rainfall and favourable temperature reduce the spread of seed borne diseases as well as risks associated with inclement weather during the late maturation and harvest period.

a. Temperature and moisture

The crop should have adequate moisture supply. A drought during the seed development period usually interrupts seed development and results in relatively ligh weight of shrivelled seeds. Water availability during seed development may influence seed vigour indirectly through its influence on the chemical composition of mature seed. For example, nitrogen content of cereal seeds generally decreases as the amount of water supplied during the vegetative development of parent plant increases (Copeland, 1976). Walter and Jenson (1970) have reported that air temperature and soil moisture availability during alfalfa seed development affect seed size, yield and germination as well as seedling vigour and subsequent yields. Seeds produced under relatively low temperatures (6 - 21^{o}C) were heavier and had a high percentage of hard seed than those produced under high temperatures (16 - 32^{o}C).

Gray (1983) reports that in onion and carrot, seed weight and embryo size are inversely related to temperature during development. He reported that in carrot, cv. Chantenay, the mean air temperature during growth of 18.5^{o}C, 22^{o} and 23.1^{o}C resulted in mean seed weight of 1.75, 1.40 and 0.94 mg respectively. However, he suggests that more work is required to confirm the results and evaluate their importance in practice. Koller (1962) showed that warm temperature during maturation of 'Grand Rapid' lettuce seed reduced dormancy. While Laude (1962) has claimed that heat stress experienced by the mother plant at seedling stage can affect dormancy of the seed harvested from mature plants. Wood *et al*. (1980) found that in sugarbeet, temperature greatly affected yield and quality of seed. Low temperature gave greater yield of larger fruit with smaller true seed and poor germination.

b. Seed maturity and vigour

As a seed matures, its potential for rapid and vigorous germination increases. Fully mature seeds have the advantage of complete physical and physiological development needed for maximum expression of vigour. Perry (1969) stresses that when seeds are harvested before maturity or have prematurely experienced fierce natural drying conditions, the prospective plant may be seriously weakened. This immaturity is likely to be a more important cause than faulty storage of the wide differences in vigour of some of pea seeds. Culpepper and Moon (1941) noted a large discrepancy between the germination of seeds and their emergence in the field, and that seedlings from small, immature seed was much less than seedlings from mature seed. In a study of seed size and maturity effect on carrots, Austin and Longden (1967) harvested seed at different stages of maturity. Seed from each harvest was graded into four size grades, and the percentage germination and field emergence determined. The percentage germination and field emergence increased with seed weight from successive harvest dates. The germination and emergence were poorer for seed harvested on the earlier, than on the later occasions, and this effect was more pronounced in the smaller size grades. The smaller seeds were from secondary or tertiary umbel order which flowered later than the primary umbel. Similar results with carrots have been reported by Jacobsohn and Globerson (1980) and Gray and Steckel (1980).

In plants with determinate flowering, the seed maturity is relatively uniform within a given inflorescence; however in species with indeterminate flowers (e.g. cauliflower, carrot and sugarbeet) harvests at any time yields seeds with varying stages of maturity and growth potential. Consequently date of harvest is a compromise to give the greatest amount of germinable, high vigour seeds from a population ranging from immature seeds to those which are ready to shatter.

c. Environment after maturation

Sometimes the seeds even they are mature cannot be harvested due to bad weather or other causes. In indeterminate type of plants, one has to wait until the majority of seeds are mature for harvest. Thus leaving the mature seeds on the plant not only causes loss due to shattering but adverse weather conditions especially rain or high temperature can cause deterioration of seed quality. Such deterioration in seed quality due to delay in harvesting have been reported in soyabean by Mondragon and Potts (1974).

d. Mechanical damage and seed vigour

After harvesting, the seeds may pass through the processes of threshing, cleaning, packaing and transporting. These processes cause impaction of seeds against each other or against some hard surface which may cause micro- or macro-cracks or other injuries. These seeds may appear normal but they show less vigour.

The drier and more brittle the seed crop, the greater the threshing injury. Barriga (1961) reported that seedlings from mechanically damaged bean seeds can be morphologically normal but exhibit slower germination, reduced growth rate, followed by delayed maturity and reduced yield.

The mechanical damage, apart from curtailing the food supply available during germination and early stage of growth, provides a focal point for microbial attack (Chetram and Heydecker, 1967). Toole and Toole (1960) found that the viability of garden bean seeds in storage decreases most rapidly in seed lots with the largest amount of mechanical damage.

e. Ageing and deterioration

The seeds reach maximum potential of vigour when they reach physiological maturity (Copeland, 1976). Thereafter the viability and vigour of the seeds declines as the seeds age, the rate of decline being the function of moisture content and temperature. The process of deterioration may start while the seed is still on the plant especially under adverse weather conditions. William and Hansen (1974) deteriorated five cultivars of radish seeds at 82% moisture and 42^{o}C temperature up to 10 days. The effect was delayed germination and smaller seedling before there was noticeable loss in germination. According to Delouche (1969) the sequence of deterioration in seeds is approximately as follows:

a. Degradation of cellular membranes and subsequent loss of control of permeability.

b. Impairment of energy-yielding and biosynthetic mechanisms.

c. Reduced respiration and biosynthesis.

d. Slower germination and slower heterotrophic seedling growth.

e. Reduced storage potential.

f. Slower growth and development of the autotrophic plant.

g. Less uniformity in growth and development amongst plants in the population.

h. Increased susceptibility to environmental stress (including micro-organisms).

i. Reduced stand producing potential.

j. Increased percentage of morphologically abnormal seedlings.

i. Loss of germinability.

Chen *et al.* (1972) deteriorated radish, squash and turnip seeds at 42°C and 100% relative humidity for a different period of time to obtain high, medium and low vigour seeds. They found that artificial ageining reduces seed vigour which was expressed in lower root size and yield in radish and turnip. Emergence, seedling development and fruit yield in squash was lower from seeds which were deteriorated to the level of low vigour. Roberts (1972) stated that deterioration leading to loss of viability in seeds can affect the yield of crop in two ways: first the decreased germination can lead to a sub-optimal population of plants per unit area; secondly, the deterioration may result in a poor performance by the surviving plants.

f. Pathogens

Studies have shown that most species have at least one recognised seed-borne disease caused by fungi, bacteria or viruses which can be serious in their effect on seed vigour and viability. Disease-causing organisms carried on or in the seed can stunt a plant's growth or kill it outright before or after the seedling emerges from the ground. Seed borne sources of disease can severely endanger seedling and plant vigour and the extent of their damage depends on their nature and the ecological balance of all the micro-organisms, in and around the seed (Thompson, 1970). Alternaria, a seed borne fungus in cauliflower can not only reduce the seed yield but also subsequent seed germination levels (Nieuwhof, 1969).

3. Effect of seed size on germination, emergence and productivity

a. Germination and emergence

A wide range of seed sizes is normally found in any seed lot. The variations in seed size within a seed lot may be due to a range of factors including genetic difference between plants; interplant competition for light, water and nutrients; position of the seed on the inflorescence; position of inflorescence on the plant or stage of maturity at harvest.

Many researchers have worked on the effect of seed size on germination and emergence in vegetables.

It has been shown in carrot by Borthwick (1931), Malik and Kanwar (1969), Austin and Longden (1967), Hunter (1971), Hegarty (1973)that larger seeds germinate better and emerge better than smaller seeds. Jacobsohn and Globerson (1980) also working with carrot c.v. Nantes found that larger seeds germinated better than smaller seeds and in more adverse conditions of deep planting and elevated temperatures, the larger seeds germinated sooner than smaller seeds.

Ibrahim (1977) graded brussels sprout and kale seeds into four size grades - 1.25 to 1.50 mm, 1.50 to 1.75 mm, 1.75 to 2.00mm and 2.00 to 2.25 mm. He found that germination level increased with increasing size for the first three grades and fell for the largest grade (2.00 - 2.25 mm). the field emergence improved for the medium size grades but did not decline for the largest group. Joubert and Rappard (1970) reported that large seeds had superior germination and emergence levels in carrot, tomato, broccoli, cauliflower, asparagus and lettuce. Hewston (1964) found increased germination and emergence percentage with increase in seed size in onion and radish cv. "Cherry Belle" (but not with cv. "Saxa"). With summer cauliflower cv. "Meteor" and cv. "White chief" the medium sized seeds were superior to larger and smaller seeds in percentage emergence, especially at greater planting depth. While germination percentage in "Meteor" had increased with seed size, it decreased in "White Chief" (Hewston, 1964). Thus he concluded that in cauliflower laboratory germination of the different size grades could not be taken as a simple guide for field establishment. Betzema and Snock (1966) and Germing (1967) have also reported better and uniform growth as a result of seed size increase in cauliflower. Whitwell (1977), though suggests higher germination percentage by large seeds of cauliflower, he warns that the advantage of using graded seed is lost when the plants are transplanted from the seedbed. Better germination and field emergence by large seeds especially at deeper planting have been reported by Alan and Locascio (1966) in broccoli; Thiele (1965) in carrot; lettuce, tomato, beetroot and cabbage; Ahmed and Zuberi (1973) in rape.

However, there are reports which indicate that in some vegetables large seed either have no better germination or in some cases smaller seeds have performed better than larger seeds. Sharples and Kuehl (1974) found that weight and size of lettuce seed was unrelated to rate of germination and germination percentage. Halsey *et al.* (1970) found that seed size had little influence on the size of various cabbage cultivars attributing increased plant growth to genetic rather than environmental factors. Lang and Holmes (1964) determined that neither germination percentage nor rate of germination was influenced by the size of swede seeds. It is possible for medium or small seed of one stock to be as good as or even superior to large seed from another stock (Wood, Longden and Scott, 1977).

b. Seed size and productivity

The large seeds having greater initial capital (larger embryo and reserve), will produce seedlings which are heavier with larger cotyledons and first leaves than those from the small seeds (Wood *et al.*, 1977). The early advantage would persist at least during the early stage of growth. In some species this early advantage may continue throughout the crop maturity e.g. in sugarbeet (Scott *et al.*, 1974), swede (Lang and Holmes, 1964) or stop after a stage of growth, e.g. in carrot (Austine and Longden, 1967; Jacobsohn and Globenson, 1980). Crops with a short growing season and a lower plant density where plant competition is minimum, the effect of seed size would be expected to be much more evident (Wood *et al.*, 1977).

Superior yields as a result of larger seeds have been reported by Joubert and Rappard in carrot, tomatoes, sprouting broccoli, cauliflower, asparagus and lettuce. In broccoli they found that plants grown from seeds bigger than 1.75 mm were earlier, central heads were heavier and the yield was significantly better than that from control seed samples or from plants grown from seeds smaller than 1.75 mm. While in cauliflower c.v. "Cumulus" plants from the biggest seed (above 1.75 mm) were stronger and grew more vigorously than those from smaller seeds. The stand and the uniformity of the plants from bigger seeds were better and the harvesting period was shorter (Joubart and Rappard, 1970). Hewston (1964) reports that the cauliflower cv. "Delta" which has comparatively shorter plant height and spread, gave earlier and more uniform curd size with larger seeds but he did not find similar results with cauliflower cv. "White Chief". He suggested that cauliflower cv. "White Chief" having larger height and spread than cv. "Delta" experienced earlier plant competition and so yield advantage could not be achieved. Tompkin (1966) found higher earlier yield in sprouting broccoli with larger seeds but the total yield for the whole season was not affected by seed size. Betzema and Snock (1966) also reported a more uniform and better crop of cauliflower from larger seeds as compared to smaller seeds. Hannmaiah and Andrews (1973) divided turnip and cabbage seeds into large, medium, and small seed groups. They found that while in turnip, the yield was superior with increasing seed size all through the growing season, cabbage yield did not significantly increase with seed size although the large seed of cabbage exhibited superior performance in most of the laboratory and field performance tests (e.g. seedling dry weight, leaf number per plant up to 50 days after planting). In carrots, many workers have found a positive yield increase with increase in seed size (Thiele, 1965; Austin and Longden, 1967, Malik and Kanwar, 1968; Jacobsohn and Globenson, 1980). However, the superiority of higher yield is seen in the early stage of growth and if left too long in the field, the advantage is narrowed even cancelled due to competition.

Ahmed and Zuberi (1973) with oil seed rape and Ahmed (1980) with *Brassica jincea* found that large seeds produced plants with a larger number of primary and secondary branches and more pods per plant, larger pods, heavier seeds, higher seed yield per plant but fewer seeds per pod as compared to plants produced from smaller seeds. With lettuce fresh weight of crop increased with increase in seed weight provided there was no inter-plant competition (Scaife and Jones, 1970).

However, the effects of large seed on yield or yield component have not always been positive. Ibrahim (1977) in kale and brussel's sprouts, Hewston (1964) in cauliflower cv. "Meteor", Salter and Fradgley (1964) in autumn cauliflower, Major (1977) in rape, Salih and Salih (1980 in broad bean, Hardenberg (1942) in red kidney bean and robust field bean did not find any effect of seed size on yield. This is attributed to the inter-plant competition for light, water and nutrients. Plants growing from large seeds experience inter-plant competition sooner and thus the advantage of using large seeds may diminish and the crops from larger and smaller seeds may eventually attain similar yields.

4. The Effect of Mineral Nutrition on Seed Yield and Quality

The effects of mother plant mineral nutrition on seed quality has been discussed by several authors in the last decade including Perry (1972), Austin (1972), Pollock and Roos (1972). One of the early investigations concerning effects of all the main nutrients, N, P, K and organic manure in a range of combinations was by Claypool (1932), who studied the effects of mineral nutrition and farm yard manure on seed yield, seed size as thousand seed weight of lettuce. He found that for seed yield and size nitrogen was the main factor. Phosphorus was the second limiting factor for seed yield and size while potassium had no apparent benefit in seed development.

Many workers have studied the effect of mineral nutrition on seed yield and quality of tomato (Anisimov and Popova, 1954; Varis, 1979; George *et al.*, 1980; Rai, 1980; Mahmood, 1982). Anisimov and Popova (1954) found that higher levels of phosphorus fertilizer applied to the mother plant resulted in seeds which produced not only taller and vigorous seedlings but earlier fruit ripening and more fruit yield in the progeny. Varis (1979) and George *et al.* (1980) concluded that higher levels of phosphorus applied to mother plants grown in greenhouses increased the total seed yield and that the combination of higher nitrogen and phosphorus increased the germination and seedling emergence rates of progeny. However, in their second experiment, they found that increased mineral nutrition while not significant for seed yield, gave rise to significant improvement in seed quality. Rai (1980) stated that if nitrogen was applied to tomatoes at rates above 500 kg/ha the seed yield was reduced. Phosphorus above 600 kg/ha gave higher seedling emergence than at 300 kg/ha. NP interactions had significant effect on mean seed weight. He concluded that although quicker emergence of seedlings was achieved by applying higher levels of phosphorus to the mother plant, overall yield and quality of seed were not further improved by excessively higher levels of nutrients. Mahmood (1982) also working with tomato used two levels each of N, P and K to find their effect on seed yield and quality. He found that seed yield and seed number per plant were significantly higher at higher levels of nitrogen and its interaction with higher levels of phosphorus. He determined the seed quality in terms of seed weight, germination percentage, seedling emergence percentage, normal seedling percentage, germination after controlled deterioration at higher temperature and moisture and the cold test. Potassium reduced the germination percentage, 100 seed weight and number of normal seedlings. Interaction of NK, NP and NPK at higher levels reduced the 100 seed weight while N main effect and NP and NPK interactions at high levels increased the germination percentage. High PK interactions gave better germination after the cold test but the controlled deterioration test produced an inconsistent result. There was no effect of mother plant treatment on the fruit yield of progeny but the seed yield of progeny was significantly reduced by P and NPK at high levels.

Austin (1966b) grew pea in vermiculite and watered with four different nutrient solutions. He examined the effect of mother plant nutrition on the growth of progeny. He found that the seeds obtained from phosphorus deficient plants contained much lower phosphorus concentration than seeds obtained from plants not deficient in this element. Differences in the supply of mineral nitrogen had little effect on the chemical composition of seed. The low phosphorus seeds, when grown in cultures deficient in phosphorus, produced plants which gave 20 - 25% lower yields in haulm and seed weight than high-phosphorus seeds. But when these seeds with low phosphorus content were grown in cultures not deficient in phosphorus, there were no differences in the seeds' performance. Similar results have been obtained when low- and high-phosphorus seeds were grown on a fertile soil. Hawthorn and Pollard (1966) also working with pea but in field conditions reported that the addition of nitrogen decreased the pea seed yield and germinability while application of phosphorus from 0-150 lbs/acre (0-168 kg/ha) produced no significant difference in bean seed yield or viability. Browning (1980) found that in green-house pea seed production experiments, increasing the levels of nitrogen supplied to the mother plant resulted in increased nitrogen content of the seeds. Material from high N treatments was generally of high vigour as evidenced by lack of hollow heart, low conductivity value of seed leachate, larger seed size, larger resulting seedling size and good field emergence. Browning also found that differences in plant phosphorus supply and seed P content had less effect on seed vigour than nitrogen. Seed yield and seed vigour in a second generation greenouse grown crop were not affected by the treatments of the first generation crop. This result differs from the work of Hawthorn and Pollard (1966) where they reported that higher nitrogen reduced the seed quality (germinability). However, in his field experiments where there were adequate P and K in the soil, Browning (1980) did not find differences in seed treatment content or seed vigour when fertilizer was applied to the plant in the field. After comparing the greenhouse and field work, she recommended that temperature at the seed maturation stage may have greater effect on seed vigour than the effect of nitrogen. Browning and George (1981) reported that in one experiment higher doses of nitrogen to the pea plant in the green house made the developing seeds more susceptible to higher incidence of seed bleaching. However, hollow heart was high in plants receiving low nitrogen and high phosphorus. Seed bleaching and hollow heart can each cause low vigour in pea seeds.

Harrington (1960) studied the germination of carrot, lettuce and pepper seeds under severe N,P,K or Ca deficiencies to the mother plant grown in sand culture. He found that while seed yield was depressed by low N, P, K or Ca treatments, the germination of normal seeds from low N and P treatments was usually no different from complete solution treatment but K deficiency resulted in lower germination in some experiments and Ca deficiency resulted in lower germination in carrot and pepper experiments. Hawthorn and Pollard (1958) working with lettuce found that the application of nitrogen (up to 80 lbs/acre) increased the seed yield but further applications had no effect. However, nitrogen had no effect on either time of seed maturity or viability. Phosphorus had no measurable effect on seed yield, time of maturity, plant height and seed quality. But Hawthorn and Pollard did not use any other tests to determine the qualities of seeds produced in their experiment.

Soffer and Smith (1974) found increased seed yield of lettuce with an increase in nitrogen applied to mother plants but nitrogen did not correspondingly increase the seedling performances. Maxon Smith (1976) grew lettuce plants in a glasshouse border soil to crop maturity and then lifted and potted. He supplied nutrition at intervals to the potted plants which contained nitrogen and potassium solution with (15 ppm) or without phosphorus. While the effect of phosphorus on the seed yield was conflicting (in one experiment, there was increase in seed yield with no phosphorus), the mean seed weight, germination percentage and progeny performance were unaffected by phosphorus application.

Austin and Longden (1966) in their work with carrots examined the effects of nutrition with nitrogen, phosphorus, potassium and farmyard manure on the seed yield and quality. Their results showed that the seed yield responses were significant and each of the main nutrients and farmyard manure gave better seed yield than the control plots with no manure or fertilizer. There was no significant difference in germination caused by manurial treatments although they were above minimum accepted 60%. The chemical composition of seed produced in 1963 and 1964 was affected by nitrogen and farmyard manure dressings, but these variations did not affect the progeny performance. The seeds with lowest phosphorus concentration were obtained from plots which had received nitrogen but no phosphorus fertilizers. The root yield as determined by total weight from such seeds were significantly lower than those from seed containing higher concentration of phosphorus.

In another experiment, Austin (1966a) grew watercress *(Rorippa nasturtium aquaticum*(L.) Hayek in sand culture and supplied nutrient solutions containing either 0.2, 1.0 or 4.0

mg/l of phosphorus. The phosphorus content of the seeds increased significantly with increase in its supply in the solution. The seeds with higher phosphorus content, when grown in phosphorus deficient substrate, produced plants which were larger than the plants produced from seeds which had lower phosphorus content. However, these differences in plant growth lasted only until the plants were 7 - 9 weeks old. If the plants were left until 16 to 20 weeks, the differences in plant growth were not measurable. The watercress seeds with different phosphorus content if grown in fertile medium, failed to show any differences in plant height. Also the different levels of phosphorus supply in the first generation had no measurable effect on 6½ week old plants in the third generation. Thus it appears from the work of Austin (1966a, 1966b) and Austin and Longden (1966) that the effect of increased concentration of nutrients in the seed may influence the growth of seedlings in its early phase of growth and only if grown in a deficient medium.

In a radish crop Singh and Cheema (1972) applied 100 and 200 kg of nitrogen and 50 and 100 kg of phosphorus per hectare along with different levels of irrigation. Higher dose of nitrogen (200 kg/ha) had significant seed yield increase over low dose (100 kg/ha). Higher dose of nitrogen also increased the 1000 seed weight and 'A' grade seeds over lower dose but had no effect on seed germination. Phosphorus had no effect on seed yield, 'A' grade seed, 1000-seed weight or germination percentage.

The increase in protein content of bean seed and better seedling performance as a result of nitrogen has been reported by

Ries (1971). Gavras (1981) studied the effect of mother plant nutrition on french bean (*Phaseolus vulgaris* L.) seed yield, quality and progeny performance and found that higher seed yields were obtained with higher nutrient levels tested but the high seed yields were not generally accompanied by high seed quality. N and K increased both seed yield and quality but P increased the seed yield and decreased the seed quality. N, P and NPK interactions were found to be important for bean seed quality because their significant effect was similar and constantly present in most of the vigour components. He suggested a high level of N and moderate level of P for better seed quality. Mother plant nutrition was found to have no effect on seed yield of the progeny. Liaw (1982) also working with french bean used combinations of 0.6, 1.8g N and 0.3, 2.4 g P per plant in one experiment and 0.5, 1.0, 1.5, 2.0 g N and 0.3, 0.9, 1.5, 2.1 g P per plant in another experiment with fixed potassium level. The results showed that higher hundred-seed weight was produced by low application of nitrogen; but high application of phosphorus increased the hundred-seed weight. High levels of nitrogen produced seeds which were more vigorous with a lower conductivity reading, and gave better seedling emergence with the cold test. Increased levels of phosphorus and potassium gave an adverse conductivity reading (i.e. a high level). The effect of interaction between nitrogen and phosphorus was significant, treatment of high nitrogen and low phosphorus gave seeds with a lower conductivity reading (i.e. more vigorous seeds). These seeds were high in nitrogen content and performed better in the field. Application of phosphorus on the other hand produced seeds which were lower in percentage germination and germinated slower. Liaw further stated that in field emergence, plants receiving low phosphorus performed better. Application of potassium, although increased its seed content, the seed performance was less favourable in seedling evaluation and conductivity tests. Thus it appears that nitrogen generally increases the seed vigour of beans, phosphorus decreases it while the effect of potassium is not clear.

Recent work of Osman (1982) on pepper *(Capsicum annuum* L.) indicates that high levels of N (9.5 g/pot), P (3.2 g/pot) and K (14.0 g/pot) increased the fruit and seed yield as compared to lower levels of these elements (7.75 g/pot N, 2.4 g/pot P and 11 g/pot K). The seed quality was also improved with the high levels of nutrients as indicated by increased hundred-seed weight, germination after controlled deterioration and percentage normal seedlings. He also found that the seeds obtained from the fruits from the lower positions in the plant were superior in seed quality than the seeds from higher positions. He further reported that mother plant nutrient treatment produced no marked influence on the fruit and seed quality. However, there was some interaction effects of mother plant nutrition on seed quality but they showed relatively low correlation with their effect on first generation.

Iwata and Eguchi (1958) examined the effects of phosphorus and potassium applied at different growth stages on seed yield and quality of chinese cabbage *(Brassica chinensis* L.*)*. While the potassium supply only affected the seed yield in the case where it was with held during the very early stages; phosphorus, especially in the early stages, was necessary for good seed yield. For seed quality they measured the phosphorus concentration in the seed, percentage of germination and the radicle elongation rate. Their results indicated that the earlier the stage of growth at which phosphorus supply was stopped, the lower was the seed phosphorus concentration. There was no difference in germination percentage among treatments but the rate of radicle growth was shown to increase with increased phosphorus application during seed development. Application of potassium did not affect the seed quality. Eguchi (1960) also studied the effect of nitrogen fertilizers applied at different stages of growth in cabbage *(Brassica oleracea* var. *capitata* L.) and chinese cabbage. He found that:

a. nitrogen applied at bolting stage increased the number of secondary branches, flowers and fruits
b. application at flowering stage resulted in high percentage of fruit setting
c. application at bolting time gave higher seed yields.

However, he did not find significant differences in terms of thousand seed weight or germination percentage.

The importance of phosphorus on flax and rape seed has been investigated by Szukalski (1961a, 1961b). In a pot experiment he applied different levels of phosphorus before and after sowing, including post-emergence. As a result, seeds were obtained with a different percentage phosphorus. The influence of phosphorus content in the seed upon yield was further investigated in pot experiments in pure quartz sand and in soil. Seeds with high concentration, sown in soil which was low in phosphorus, germinated faster and uniformly, producing plants which flowered earlier, had better growth at beginning of the vegetative period and a higher final yield. But in soil high in phosphorus this difference in growth was observed in the beginning, but not in the final yield. Szukalski (1975) in another experiment used horsebean, oat, summer wheat and flax to see the effect of increasing levels of plant nutrition. on subsequent seed content and its effect on the seed performance. He found that increasing the N and P in the fertilizer increased their content in the seed. Potassium content of seed was not affected by increasing potassium in the fertilizer. He found that in the experimental pot conditions, high contents of the components in the seeds had positive influence upon the initial growth of the plant (clearly in 1964, less consistently in 1965). In the microplot experiments, the positive influence remained to the end of the growth period, resulting in the significant differences in yields.

Ahmed (1982) found that with onion, under greenhouse conditions, nitrogen up to medium level (2400 mg/plant) increased seed yield but phosphorus and potash had no significant effect excpet in combination with nitrogen. The seed yield increase was accompanied by reduction in seed quality. In the field crop of onion he found that neither level of nitrogen nor time of application had any effect on seed yield but low nitrogen levels, especially at flowering time improved the seed quality. Application of potassium had beneficial effect on seed quality. Although the fertilizer rates for producing mother bulbs in their first season did not result in significant seed yield increases, he found that the mother plant nutrition in the seed year improved the seed quality. From the seed vigour tests used he found high correlation between field emergence and seed germination after controlled deterioration. He suggested that controlled deterioration test may be an indicator of potential onion seedling emergence in the field.

Fox and Albrecht (1957) demonstrated that with wheat the soil fertility influenced the subsequent seedling vigour. Moderate amounts of phosphorus improved seedling emergence but large quantitities depressed it. They also reported that fertilizer for high yield of wheat may not be accompanied by good quality of wheat seed.

Lopez and Grabe (1973) also working with wheat found that increase in nitrogen application increased the protein content of seed which in turn increased the rates of water absorption and oxygen consumption of germinating seeds. The seeds with a higher protein content had a faster rate of germination and developed into larger seedlings with a higher dry matter content when grown in nitrogen-deficient soil. Schweizer and Ries (1969) have also reported that increasing the protein content of wheat and oats through N fertilization or by application of sub-lethal doses of simazine, terbacil or atrazine resultes in seedlings with increased vigour. Foliar application of N has been recommended by Ries *et al.* (1970) to improve the wheat seed protein and yield. Holzman (1974) also found that wheat seeds with high N content produced taller and heavier seedlings compared to those of low N. The general trend is that N fertilization directly affects N content of wheat seed which is an important factor governing seedling performance. Abdul-Baki (1980) stated that the increase in seed protein due to high N apparently is restricted to those storage protein species abundant in endosperm and does not affect the protein of the embryo or cellular membranes. The role of endosperm reserve proteins is important during seedling growth. Their role in seedling growth becomes even greater when seeds are planted in N-deficient soil. Abdul-Baki postulated that the denser seeds within a size range being more vigorous than the lighter seeds probably relates to the protein/starch ratio of the seeds. The density of starch is about 0.8 and that of proteins ranges from 1.30 to 1.45 cm^{-3}. Since the increase in protein content of the endosperm is associated with decrease in endosperm starch, any increase in protein content raises the density of the seed. Hence the trait of high seed density, with high protein and low starch contents, may be the same factor that indicates high seed vigour. Dale (1977) states that growing plants require, utilize and produce a wide range of nitrogenous compounds. But the direct requirement of a growing tissue for nitrogen is only one stage at which the supply of that element may control development: there are also indirect controlling mechanisms. He also states that nitrogen supply may control size and activity of the photosynthetic system and thus production of carbon assimilates essential for growth. In the germinating seed, the soluble nitrogenous compounds are translocated from endosperm at a much faster rate than dry matter as a whole. From 48 to 96 hours from sowing, 40 - 50% of the mobilized nitrogen is found in the roots but coincident with emergence of seedling into light this figure tends to decrease as more nitrogen is utilized in leaf development. However when the grain nitrogen content is small (<1.4%), and in the absence of an exogenous supply, this change in pattern of partition of nitrogen is less marked and roots continue to be favoured.

From the above review it has been seen that the effect of mother plant mineral nutrition on the seed quality was varying and at times conflicting. The seed quality was determined by seed size or weight, germination percentage, seedling growth and the ability of seeds to germinate or emerge under adverse conditions. In some experiments reported the effect of main nutrients was evident only in combination with other nutrients.

In tomato, higher level of phosphorus in combination with nitrogen or potassium improved the seed quality but in beans and peas, high level of nitrogen in combination with low phosphorus improved the quality. In beans and peas high level of phosphorus either depressed the seed quality or had no effect. In onion, higher application of nitrogen depressed the seed quality but potassium improved it while in cabbage nitrogen had no effect.

Lettuce seed quality was not affected by mother plant nutrition.

However, many workers have reported that the effect of mother plant nutrition was evident in the early part of the seedling growth and under poor soil conditions only. The difference in seedling growth was not noticed if grown in fertile medium or the differences disappeared after certain periods of time.

5. The Effect of Mineral Nutrition on Cauliflower Seed Yield

According to Nieuwhof (1969) a cauliflower crop with a curd yield of 11,000 - 18,000 kg per hectare utilizes the following quantities of nutrients from the soil:

nitrogen - 143 - 234 kg/ha

phosphorus - 22 - 37 kg/ha

potash - 128 - 209 kg/ha.

More work has been done on the effect of plant nutrition on curd yield than on seed yield. Usually, the summer and autumn varieties have responsed positively to the application of nitrogen by producing higher yields and larger curd size (MAFF, 1973; Clever, 1969; Dhesi *et al.*, 1964; Sharma and Singh, 1963; Tayde and Joshi, 1974; Singh and Singh, 1970: Mathur and Chauhan , 1971; Chaudhary and Yawalker, 1969; Pinpini (1965).

Several workers have found that when the level of soil phosphorus is low, there is an increase in curd yield due to application of low doses of phosphorus but it soon reaches a ceiling and further applications fail to increase yield (Sharma and Singh, 1963; Dhesi *et al.*, 1964; Chaudhary and Yawalker, 1969; Nieuwhof, 1969).

Similarly potassium application increases the curd yield when the soil level is low (Cleaver, 1969; Nieuwhof, 1969) but in soil with moderate potassium, there is no effect on curd yield (Dhesi *et al.* 1964; Chaudhary and Yawalker, 1969).

For seed production, the soils which are suitable for growing normal cauliflower crops, are generally suitable for seed production. However, the larger and more compact curd is not always indicative of high yield of seed. Nieuwhof (1969) states that nitrogen seedlings for seed crops should not be too heavy as excessive vegetative growth is to be avoided, and excessive nitrogen favours browning and rotting of stumps, which may result in lowering of seed yield, but he does not make specific recommendations as to suitable quantities of nitrogen.

Pandey *et al.* (1979) working in India grew a mid-season cauliflower cutlivar Hissar-1 in a sandy loam soil for two consecutive years. They applied nitrogen at 0, 50, 100 and 150 kg/ha and phosphorus at 0, 50 and 100 kg/ha. They found that nitrogen at 50 kg/ha gave increased seed yield over the control but higher quantities failed to give an increase in seed yield. Phosphorus at 100 kg/ha increased the seed yield significantly over the remainder of the treatments. In the second year phosphorus at 100 kg/ha was similar to 50 kg/ha but both 50 kg/ha and 100 kg/ha had produced significantly higher seed yield over the control (0 kg/ha). They concluded that 50 kg N and 100 kg P_{205} per hectare was the best combination for that type of soil and cultivar. Singh *et al.* (1960) recommended 40 lbs (44.8 kg/ha) of P_2O_5 and 120 lbs per acre (134.4 kg/ha) of nitrogen split into three applications for the best yield of cauliflower cv. Snowball seed in a fertile clay loam soil. Shah and Hussain (1978) in their three year trial in Pakistan found that nitrogen at 100 lbs per acre (112 kg/ha) gave significantly higher seed yields over no nitrogen. But phosphate and potash failed to give a significant seed yield increase. Novak (1974) reports that nitrogen up to 150 kg/ha along with farmyard manure and intensive irrigation is advisable for high quality heads for consumption but have adverse effect on seed production. Such conditions are very favourable for bacterial infection of heads, seed stalk bases and stumps when an effective chemical control is not possible. The rot mostly affects the best quality with the largest and most compact heads. In a three year trial in heavy loam slight alkaline soil with medium phosphorus, four cauliflower cultivars were used with eight different fertilizer treatments. He reports that doses of 142 - 152 kg/ha of mineral nitrogen applied before planting and in the first stage of growth reduced the yield of seed by 24.3% compared to lower doses of mineral nitrogen (62 - 90 kg/ha) applied at the same time and way. He also found that a medium level of farmyard manure (36 ton/ha) was beneficial only with low (22 - 32 kg/ha) or medium (62 - 92 kg/ha) of nitrogen. Plants receiving low nitrogen levels showed less decay than others. Gill *et al*. (1975) used four doses of phosphorus (from 62.5 to 250 kg/ha) and four doses of nitrogen (125 to 500 kg/ha) while all the phosphorus was applied before transplanting, nitrogen was applied in four equal split doses. They found significant seed yield increase as both nitrogen and phosphorus were increased through increase in curd size and plant height. The highest doses of nitrogen (500 kg/ha) and phosphorus (250 kg/ha) did not decrease the seed yield as found by other authors who reported that very high levels of nitrogen decrease yield due to rotting (Novak, 1979). Since they used the nitrogen in four split doses, it is possible that plants received a uniform nitrogen supply throughout the growing period and were not affected at any time by excessive nitrogen. Eguchi (1960) had also reported that with cabbage and chinese cabbage if the nitrogen is applied in split doses, the one applied at bolting increases the secondary branches, number of flowers and fruits and ultimately the seed yield. However, if the high dose of nitrogen is applied at one time, it has a more adverse effect on seed yield. According to Nieuwhof (1969) if the level of nitrogen is very high, it may give rank growth of the seeding plant, and too much growth after bolting may produce lodging which results in decrease in yield and quality of seed. Higher doses of nitrogen may also favour sprouting of young shoots during ripening of the seeds - particularly when, during seed setting, a dry weather is followed by a relatively wet period.

6. The Effect of Mineral Nutrition on Mustard Seed

The mustard broad leaf *(Brassica juncea* (L) Czern & Coss.) is usually cultivated for consumption of its leaves which are consumed as a vegetable. There are not reports in the literature on the effect of N P K on the seed yield of mustard broad leaf. However, effect óf mineral nutritian on winter and summer rape *(Brassica napus* L.), turnip *(Brassica comprestris* L.) Indian or brown mustard (*Brassica juncea* L. Czern and Coss.) have been reported.

In winter and summer rape in England, there was increase in seed yield with nitrogen application but doses higher than 200 kg/ha depressed it (Scott *et al.*, 1973). The normal effect of nitrogen on growth is to increase the height and vigour of the crop, to increase the branching of the infloresence and total dry matter. Nitrogen when applied in spring has a considerable seed yield increase but autumn application has a conflicting effect on seed yield (Holmes,1980).

Bhan *et al.* (1975) used three cultivars of mustard with five different plant spacings and three levels of N P K combinations. The N P K combinations were $N_oP_oK_o$, $N_{60}P_{30}K_{30}$ and $N_{120}P_{60}K_{60}$ kg/ha. The experimental field was sandy loam with low fertility. Both fertilizer combinations gave significantly higher yield over the control ($N_oP_oK_o$). The yield increase was due to increase in number of branches, siliqua per plant, siliqua length and seeds per siliqua. Increase in seed yield of mustard due to addition of nitrogen has been reported by various other workers including Sen *et al.* (1975), Bishnoi and Singh (1979), Jain and Jain (1979) and Pandey *et al.* (1979). Although application of nitrogen up to 120 kg/ha has increased the seed yield (Bhan and Singh, 1976), higher levels than 60 kg/ha under irrigated conditions was not economic (Sen *et al.*, 1975).

Effect of nitrogen on seed size has been conflicting. While the application of nitrogen had increased the seed size by increasing thousand-seed weight in summer and winter rape (Scott *et al.*, 1973) and mustard (Bishnoi and Singh, 1975); it had no effect on seed size of Indian mustard (Beech and Norman, 1974; Sen *et al.*, 1975) and it decreased the seed size of rape and mustard (Majundar and Sandhu, 1964; Singh and Moolani, 1970).

There is no report of the effect of nitrogen on other seed quality of mustard but in almost all cases nitrogen has increased the protein content of rape seed (Holmes, 1980). Effect of increased protein of brassica seeds on seed vigour have not been reported.

Phosphorus fertilizer seldom has large effect on the seed yield of rape seed, mustard and in general terms, the magnitude of effect is related to soil phosphorus status (Holmes, 1980). In India, in low fertility soil, phosphorus up to 50 kg/ha increased seed yield of mustard (Bhan and Singh, 1976). But when the soil was comparatively rich in nutrients, application of phosphorus had no effect on seed yield (Jain and Jain, 1979;

Pandey *et al.*, 1979). However, it is reported that in Poland phosphorus up to 180 kg/ha increased rape seed yield in soils with low, medium and high phosphorus status (Dembinski *et al.*, 1969). In soil with lower status of phosphorus, there was large response in seed yield.

Protein content of seed is little affected by phosphorus fertilizer. There is consistent evidence that effects are small or non-existent on winter or summer rape (Holmes, 1980). In low yielding crop of Indian mustard (brown mustard) there was a reduction in protein content of seed due to addition of phosphorus (Majundar and Sandhu, 1964). The effect of phosphorus on seed size has not been reported.

Although oil seed rape crops take up large amounts of potassium, they do not often respond, in terms of seed , to the application of potassium fertilizer. While potassium does increase yield,this is normally on soils of very low potassium status (Holmes, 1980). In soil with low nutrient level, 25 kg/ha of potassium increased seed yield of mustard (Bhan and Singh, 1976) but in comparatively fertile soil it failed to increase seed yield (Jain and Jain, 1979; Pandey *et al.*, 1979). But in turnip, Sandhu *et al.* (1966) had found no seed yield increase due to potassium application even in soil which had low potassium content.

From the above review of the literature it appears that the addition of nitrogen increases the curd yield of cauliflower, but does not necessarily increase the seed yield. On the other hand, higher levels of mineral nitrogen predispose the curds to rotting which results in lower seed yield. However if the nitrogen is split into several applications, adverse effects due to rotting of curds and lodging of branches may be minimized. Phosphorus and potassium increase seed yield in soil low in these nutrients. The effect of mineral nutrition on seed quality of cauliflower has not been reported.

Increasing the level of nitrogen up to 120 kg/ha has increased mustard seed yield but its effect on seed size is conflicting. Phosphorus and potassium may increase seed yield in soils with low levels of these nutrients.

As a result of the development of precision sowing, demands for crop uniformity and a satisfactory crop stand, there is increasing demand for high quality seeds in vegetable industry. The present studies were undertaken with a view to investigate the effect of mineral nutrition on seed quality of cauliflower and mustard broad leaf.

MATERIALS AND METHODS

MATERIALS AND METHODS

General Materials and Methods

For all the cauliflower experiments, cultivar Snowball which is an early summer type was used. Seeds were obtained from Suttons Seeds Company. The cv. Snowball makes a relatively small plant with erect leaves. It can be cultivated at relatively high densities and is suitable for production under glass as well as outside. The curds of snowball are bright white, a little knobly but quickly become loose; sometimes riceyness occurs and under unfavourable growing conditions, the plants are likely to button. Many strains of snowball have been developed.

Snowball forms curds with or without cold treatment but requires cold treatment for flowering (Sadik, 1967).
The seeds were sown in early January in Levington Universal Compost in black plastic trays (27 x 22 x 6 cm) and kept in a propagation glasshouse with the night and day temperature of 15° and 20°C respectively.

The seedlings were pricked off after 10 days of sowing into "Vacapack 245" (5 x 5 x 5 cm) using Levington Potting Compost and the plants were transferred to another glasshouse with night temperature of 5°C and day temperature of 10°C, where they were kept there until they developed 4 - 6 true leaves. The plants were hardened off for a week by placing them in a cold frame before transplanting.

After transplanting, Disulfon, an organophosphorus insecticide was applied at the base of each plant as a preventative measure against cabbage root fly *(Delia brassicae)*.

Cauliflower Seed Production

Experiment 1

Glasshouse Experiment

N P K 3 x 3 x 3 Factorial

Experiment 1 was carried out in the field station glasshouse at Bathampton. The north-south oriented glasshouse was not heated but was automatically ventilated at 20°C. The purpose of the experiment was to study the effect of different levels of nitrogen, phosphorus and potassium on cauliflower seed yield and quality.

Planting Media

Based on the work at the Glasshouse Crops Research Institute (Bunt, 1976), a mixture of sphagnum peat and fine sand in the ratio of 3 : 1 by volume was used as planting media. To bring the pH of the mixture to the desired level and also to supply the micronutrients, the following materials were added to the mixture and mixed thoroughly.

Ground limestone	- 2.25 g/litre of mixture
Magnesium limestone	- 2.25 g/litre of mixture
Fritted trace element WM 255	- 0.375 g/litre of mixture

The fritted trace element WM 255 contains the following percentages of elements (Bunt, 1976):

Boron	1%
Copper	4.3%
Iron	13.8%
Manganese	5.4%
Molybdenum	1%
Zinc	4.3%

Plastic pots with a diameter of 25 cm and capacity 10 litres were used for planting.

Nutrient Levels

Based on the absorption of nutrients by cauliflower (Nieuwhof, 1969) and the leaching of nutrients through peat sand mixture (Bunt, 1976), the following nutrient treatments were determined:

N_1: equivalent to	600 kg/ha applied at	3 g N/pot
N_2:	900 kg/ha	4.5 g N/pot
N_3:	1200 kg/ha	6.0 g N/pot
P_1:	250 kg P_2O_5/ha	1.25 g P_2O_5/pot
P_2:	375 kg P_2O_5/ha	1.875 g P_2O_5/pot
P_3:	500 kg P_2O_5/ha	2.50 g P_2O_5/pot
K_1:	500 kg K_2O/ha	2.50 g K_2O/pot
K_2:	650 kg K_2O/ha	3.25 g K_2O/pot
K_3:	800 kg K_2O/ha	4.00 g K_2O/pot

The treatments in the experiment were all possible combinations of the selected nutrient levels (e.g. 3 x 3 x 3 = 27 treatments)as shown below:

1	$N_1P_1K_1$
2	$N_1P_1K_2$
3	$N_1P_1K_3$
4	$N_1P_2K_1$
5	$N_1P_2K_2$
6	$N_1P_2K_3$
7	$N_1P_3K_1$
8	$N_1P_3K_2$
9	$N_1P_3K_3$
10	$N_2P_1K_1$
11	$N_2P_1K_2$
12	$N_2P_1K_3$
13	$N_2P_2K_1$
14	$N_2P_2K_2$
15	$N_2P_2K_3$
16	$N_2P_3K_1$
17	$N_2P_3K_2$
18	$N_2P_3K_3$
19	$N_3P_1K_1$
20	$N_3P_1K_2$
21	$N_3P_1K_3$
22	$N_3P_2K_1$
23	$N_3P_2K_2$
24	$N_3P_2K_3$
25	$N_3P_3K_1$
26	$N_3P_3K_2$
27	$N_3P_3K_3$

The treatments were arranged in a factorial randomized block design with four replications.

One third of the total nutrients were applied as a base dressing before transplanting. For supplying nitrogen (N), phosphorus (P) and potassium (K), the following fertilizers were used:

Ammonium nitrate	34% N
Superphosphate	18.5% P_2O_5
Potassium nitrate	45% K_2O and 13% N

The remaining two third nutrients were decided to be applied as liquid feed. The concentration of liquid feed was as follows:

Nutrients	Concentration
N_1	83.25 ppm
N_2	125.0 ppm
N_3	166.25 ppm
P_1	34.75 ppm
P_2	52.13 ppm
P_3	69.63 ppm
K_1	69.63 ppm
K_2	90.38 ppm
K_3	111.25 ppm

The liquid feed was formulated from the following laboratory grade fertilizers:

Ammonium nitrate	35% N
Monoammonium phosphate	25% P and 12% N
Potassium nitrate	45% K_2O and 13% N

Liquid feeding started 3 weeks after planting. 4 ml of mixture of stock solution was mixed with 800 ml of water and applied at each feeding. Two liquid feedings per week were given.

Crop Programme

Seeds sown	5 January 1981
Transplanted	25 March 1981
First application of liquid feed	17 April 1981
Final application of liquid feed	19 May 1981

The plants appeared to be normal and satisfactory until after curd maturity but before they became loose, segments of curds of some plants showed water soaked appearance and became brown (Plate 1). Spray with fungicides like benlate or roveral had no effect and the affected parts started rotting in a few days time. Following consultation with chemists at the National Vegetable Research Station (N.V.R.S.), Wellesbourne, it was later confirmed that the symptoms were of the boron deficiency (Scaife, 1981). The symptoms of boron deficiency developed so suddenly and severe that the experiment had to be abandoned.

Although this did not provide useful evidence for the primary objectives of the experiment, it confirmed micro-nutrient work in progress at N.V.R.S. at that time and provided information for future experiments on container grown cauliflower. When plants are grown in containers, their roots are restricted to a relatively small volume. They cannot rely upon an extending root system to provide a continuing supply of nutrients. Once the roots have filled the volume of compost in the pot container, available nutrients soon will be depleted and plants will show deficiency symptoms. In the case of cauliflower, the boron supplied through fritted trace element WM 255 was either not adequate for the crop or the other factors such as leaching or alkaline nature of water may have aggravated the deficiency. Boron deficiency is usually noticed in the tip of new growth and the cauliflower head showed the boron deficiency symptoms at the time curds had attained full maturity and were about to become loose. For future experiments with cauliflower in containers, additional application of boron either in the growing media (peat/sand mixture) or spray to the plant will be helpful.

Plate 1. Cauliflower curd showing boron deficiency symptoms

Cauliflower Seed Production

Experiment 2

This experiment was conducted at the University glasshouse, Bathampton. The north-south oriented glasshouse was not heated but was automatically ventilated at 20^{o}C. This experiment was conducted in the spring and summer of 1982.

The object of the study was to find out the effect of three levels each of nitrogen and phosphorus and two levels of potassium on seed yield and quality of cauliflower cv. Snowball.

The land of the glasshouse was fallow the previous season. A week before transplanting the crop, the land was rotovated and raked, and the individual plot was marked out with string. The design was a randomized block design with four replications and two plants in each treatment. There were guard rows all round the plot. The spacing between plants was maintained at 60 cms.

The soil analysis report by ADAS indicated that the soil was of silty loam type and it had the following nutrient indexes and pH value.

Phosphorus	index 3
Potassium	index 2
Magnesium	index 3
pH	7.2

Based on the soil analysis and recommendation for growing early summer cauliflower (MAFF, 1973), the following levels of nutrients were applied.

N_1 equivalent to	50 kg N/ha	1.8 g N/plant
N_2	100 kg N/ha	3.6 g N/plant
N_3	150 kg N/ha	5.4 g N/plant
P_1	0 kg P_2O_5/ha	0 g P_2O_5/plant
P_2	75 kg P_2O_5/ha	2.7 g P_2O_5/plant
P_3	150 kg P_2O_5/ha	5.4 g P_2O_5/plant
K_1	50 kg K_2O/ha	1.8 kg K_2O/plant
K_2	100 kg K_2O/ha	3.6 g K_2O/plant

Plants in the guard rows were given N, P and K at a level equivalent to 50 kg/ha each.

The treatments in the experiment were all possible combinations of the above nutrient levels (e.g. 3 x 3 x 2 = 18 treatments) as follows:

No. of treatment	Treatment
1	$N_1P_1K_1$
2	$N_1P_1K_2$
3	$N_1P_2K_1$
4	$N_1P_2K_2$
5	$N_1P_3K_1$
6	$N_1P_3K_2$
7	$N_2P_1K_1$
8	$N_2P_1K_2$
9	$N_2P_2K_1$

No. of treatment	Treatment
10	$N_2P_2K_2$
11	$N_2P_3K_1$
12	$N_2P_3K_2$
13	$N_3P_1K_1$
14	$N_3P_1K_2$
15	$N_3P_2K_1$
16	$N_3P_2K_2$
17	$N_3P_3K_1$
18	$N_3P_3K_2$

The treatments were arranged in randomized block design with four replications. Irrigation was provided through overhead sprinklers. Against aphids and caterpillars of cabbage white butterfly, Ambush, a pyrethrum compound was used. Thiram (tetramethylthiuram disulphide) was used to check the rotting of the central part of the curd. Generally, the elongation of flower stalk took place towards the periphery of the curd and the curd in the centre did not elongate. These central parts of the curd shrivelled and some of them started rotting. The rotting of un-elongated curd is frequent in cauliflower seed production (Nieuwhof, 1969). Dle to comparatively high humidity in the glasshouse, it was not possible to check rotting even with repeated application of thiram dust. This may have affected the seed yield of cauliflower.

Individual plants were supported with stakes and tied with string to prevent the branches from falling. The crop was harvested as the pods started turning yellow.

The seed was sown on 24 January 1982, transplanted on 25 March and seed crop harvested from 5 August to 20 August 1982. The harvested crops were dried in the glasshouse for two weeks before threshing and cleaning by hand.

The results were subjected to analysis of variance and the differences were determined by least significant difference.

Effect of Nitrogen on Cauliflower Seed

Experiment 3

Latin Square Design

This experiment was conducted at the University Field Station on the campus, Bath during the 1981 season.

The main object of the experiment was to study the effect of nitrogen on seed yield and quality of cauliflower under field conditions.

The ADAS soil analysis report indicated the soil texture of the field station was silty clay loam with a pH of 7.3. The phosphorus, potassium and magnesium index of the soil was as follows:

Phosphorus	2
Potassium	2
Magnesium	3

The experimental area had beans in the previous season. After the harvest of the previous crop, the land was deeply ploughed and left over the winter. It was again rotovated in March 1981. Before transplanting, the land was raked.

The experiment was laid out in a Latin square design. The distance between plants was one metre. There were two plants per treatment.

The ADAS soil analysis report and MAFF recommendations were the basis to determine the levels of nutrients. According to MAFF (1973) recommendation, early summer cauliflower needs the following nutrients:

Nitrogen	125 - 250 kg/ha
Phosphorus	60 - 200 kg/ha
Potassium	60 - 300 kg/ha.

In the present experiment phosphorus and potassium at the equivalent rates of 75 kg/ha and 100 kg/ha were used respectively. For nitrogen, the lowest level was 50 kg/ha and treatment levels were increased by 100 kg/ha to the maximum of 350 kg/ha to give a wide range of nitrogen effects. The following levels of nitrogen were used.

N_1 - 50 kg/ha	=	5 g N/plant
N_2 - 150 kg/ha	=	15 g N/plant
N_3 - 250 kg/ha	=	25 g N/plant
N_4 - 350 kg/ha	=	35 g N/plant

Nitrogen was supplied in the form of ammonium nitrate (33% N); phosphorus in the form of single superphosphate (20% P_2O_5) and potassium in the form of potassium sulphate (50% K_2O).

After raking and marking the plots, all of the superphosphate and potassium sulphate and one third of respective applications of ammonium nitrate were broadcast and incorporated into the soil by raking before transplanting the crop. The remaining two thirds of nitrogen was applied as a top dressing, in two equal quantities, the first 3 weeks and the second 6 weeks after transplanting.

Weeding was done by hand hoe. Slug pellets were used to prevent the attack by slugs. At the time of pod formation aphids and cabbage seed-pod weevil *(Ceutorrhynchus assimilis* Payk.) were noticed. But they were timely controlled by spraying with "Ambush", a pyrethrum compound.

Pods in some plants showed the symptoms of 'whiteblister'. It is caused by *Albugo candida*. Two sprays with benlate at fortnightly intervals checked the further spread of the disease. Partial rotting of the curds, especially at high nitrogen levels, was noticed. Thiram was used to check it. No other diseases were noticed.

The whole plant was harvested when the pod started turning yellow. After harvesting, the plants were dried in the shade for two weeks before threshing by hand.

The crop programme was as follows:

Seed sown	5 January 1981
Pricked off	15 January 1981
Transplanted	10 April 1981
Harvested	23 September 1981

The cleaned and dried seeds were kept in paper bags for a month in the laboratory before vigour tests were carried out.

Cauliflower Seed Production

Experiment 4

Field Experiment

This experiment was conducted at the University Field Station, adjacent to Experiment 3.

The object of the experiment was to study the effect of phosphorus on seed yield and *quality* of cauliflower seeds. The same cultivar was used in this experiment. Land preparations and other field operations were similar to Experiment 2.

The design of the experiment was a randomized block design with three replications. There were two plants in each treatment with guard rows all round the treatment.

The nitrogen and potassium were applied uniformly. Nitrogen was applied in the form of ammonium nitrate in two equal doses, one before transplanting and another one month after transplanting. All the potassium was applied before transplanting in the form of potassium sulphate. The following levels of phosphorus were given:-

P_1	equivalent to 50 kg P_2O_5/ha	=	5 g P_2O_5/plant
P_2	100 kg P_2O_5/ha	=	10 g P_2O_5/plant
P_3	150 kg P_2O_5/ha	=	15 g P_2O_5/plant
P_4	200 kg P_2O_5/ha	=	20 g P_2O_5/plant

Phosphorus was applied as superphosphate (20% P_2O_5) in two equal applications. The first before transplanting with nitrogen and potassium and the second application 4 weeks after transplanting. The crop programme was as follows:-

Seed sown	20 March 1981
Pricking off	31 March 1981
Basal dose of fertilizer application	13 May 1981
Transplanting	13 May 1981
Top dressing	11 June 1981
Harvesting seed	11 September 1981.

The seeds were threshed after they were dry and cleaned by hand. They were stored in a packet for a month in the laboratory before testing the seed quality.

Effects of mother plant mineral nutrition on mustard broad leaf seed

Experiment 5

In this experiment the effects of three levels of nitrogen and three levels of phosphorus on seed yield and quality of braod leaf mustard (*Brassica juncea*) were examined. The experiment was conducted in the spring and summer of 1982 in North-South oriented glasshouse at the University Horticulture Unit, Bathampton.

The cultivar "Miike Giant" was obtained from Takii and Co. Ltd., Japan, via Suttons Seeds Ltd. This is a popular cultivar in Japan and grows well in the mid-hills of Nepal during the winter months. Leaves of this cultivar are crinkled and grow very large and broad with thick broad midrib. The cultivar has a slightly pungent taste. The mustard broad leaf seed crop is shown in Plate 2.

Field soil of Bathampton Field Station was used. Each plastic pot of 23 cm diameter contained 6 litres of field soil. The soil analysis report of Bathampton Field Station was as follows:

pH	7.6
Phosphorus index	6
Potassium Index	3
Magnesium Index	3

The following nutrient levels were seledcted

N_1 0.30 g N/pot equivalent to 100 kg N/ha

N_2 0.60 g N/pot equivalent to 200 kg N/ha

N_3 0.90 g N/pot equivalent to 300 kg N/ha

P_1 0.15 g P_2O_5/pot equivalent to 50 kg P_2O_5/ha

P_2 0.30 g P_2O_5/pot equivalent to 100 kg P_2O_5/ha

P_3 0.45 g P_2O_5/pot equivalent to 150 kg P_2O_5/ha

In addition to the above nutrients, each pot was supplied with 0.15 g of K_2O equivalent to 50 kg K_2O/ha.

The treatments in the experiment were all possible combinations of three nitrogen and three phosphorus levels, i.e. 3 x 3 = 9 treatments as follows:

N_1P_1

N_1P_2

N_1P_3

N_2P_1

N_2P_2

N_2P_3

N_3P_1

N_3P_2

N_3P_3

The fertilizers used in this experiment were ammonium sulphate (20% N), single superphosphate (20% P_2O_5) and potassium sulphate (50% K_2O). The amount of fertilizer for each nutrient level was calculated and one third of the ammonium sulphate and all of the superphosphate and potassium sulphate were applied as base dressing. The remaining ammonium sulphate was applied as top dressing in two equal parts, the first top dressing was a month after transplanting and the second at flowering time.

The experiment was laid out in a randomized block design with three replications. There were guard rows at both ends of the row.

Cultural detail

Seeds were sown in Levington Universal Compost in black plastic trays (27 x 22 x 5 cm) and kept in propagation with day temperatures of 20°C and a night temperature of 15°C. They were pricked off after one week in 5" plastic pots with Levington potting compost. Then they were transferred to the glasshouse with day and night temperatures of 12° and 8°C respectively. One week before transplanting, they were hardened off by transferring them to open bench. After the plants had developed 4 - 5 true leaves, they were transplanted at Bathampton glasshouse.

Crop programme

Date of sowing the seed	1 March 1982
Date of pricking off	8 March 1982
Date of transplanting	5 April 1982
First top dressing	1 May 1982
Second top dressing	20 May 1982

Watering was done by hand as required. No fungal or bacterial diseases were observed. However, the plants were sprayed with benomyl as a precaution against botrytis (*Botrytis cinerea*).

At the time of transplanting 'Fonofos' an organophosphorus insecticide, was used to prevent the attack by cabbage root fly

(*Delia brassicae*). 'Ambush', a pyrethrum compound was used to control aphids and caterpillar of cabbage white butterfly (*Pieris* spp.).

The crop was harvested after the pods started turning yellow and the seeds turned brown. The whole plant was harvested and left on the bench in the shade for a week before hand threshing They were cleaned, dried and stored in packets in the laboratory for 3 months before testing for quality.

Plate 2. Showing the mustard broad leaf plant in fruiting stage

Seed Quality Tests

Standard Germination

Eight replicates of 50 seeds were taken at random from each treatment. The seeds were placed on moist filter paper circles (Whatman grade 182) in a plastic sterile petri dish. The petri dishes were kept in an incubator with a constant temperature of 20°C and 16 hours of light.The germination was counted after 3 and 10 days. The results are expressed as a percentage of normal seedling (ISTA 1966).

1000 Seed Weight

Eight replicates, each of 100 seeds taken at random were counted from the treatment. The weight was taken in grams to the three decimal places as prescribed by ISTA (1966). The variance, standard deviation and coefficient of variation were calculated as follows:

$$\text{Variance} = \frac{n(\Sigma x^2) - (\Sigma x)^2}{n(n-1)}$$

where x = weight of each replicate in grams

n = number of replicates

Σ = sum of

Standard deviation (s) = variance

Coefficient of variation = $\frac{s}{\bar{x}}$ x 100

where $\bar{x}$ = mean weight of 100 seeds.

If the coefficient of variation did not exceed 4.0, the average 1000 seed weight was calculated by multiplying mean 100 seed weight with 10.

Emergence test

Emergence test of cauliflowers were done in a) compost and b) soil in the glasshouse and c) in the field.

a. Compost

Three replicates of 50 seeds of each treatment were sown in Levington Universal Compost in a plastic tray (21 x 15 x 5 cm). They were covered with one centimetre of compost and uniformly pressed before watering. The trays were placed on a bench in a glasshouse with day and night temperatures of 20°C and 15°C respectively. Watering was done as required. After the seedlings started emerging, the daily count of emerged seedlings was made until there was no further emergence.

b. Soil

The plastic trays (21 x 15 x 5 cm) were filled with 2 litres of silty loam field soil and three replicates of 100 seeds were broadcast in the tray. It was then covered with one cm of soil and pressed lightly and uniformly before watering. To expose the seeds to adverse weather conditions, the trays were left outside the glasshouse in the open for two weeks before they were transferred to the glasshouse. This test was conducted during December 1982 and January 1983. The total emergence percentage was noted after they were in the glasshouse for three weeks.

The minimum temperature outside the glasshouse ranged from -5° to 0°C, and the maximum 2° to 7°C. The temperature of the glasshouse was maintained at 20°C day and 15°C night.

c. Field

Field emergence test: This was conducted at the University Field Station which has silty loam soil. Four replicates of 100 seeds of each treatment were sown about one centimetre deep and covered with soil after sowing. Final emergence was noted after 4 weeks. The field emergence tests were carried out in April - May 1982 for Experiment No. 3 and in April - May 1983 for Experiment No. 2.

Controlled Deterioration Test

This test was based on the work of Mathew and Powell (1980). The moisture content of the seed was determined as described in the International Rules for Seed TNsting, 1966. Three replicates of one gram seed from each treatment were weighed accurately. To raise the mositure percentage of seed slowly to the desired level of 20%, the seeds were placed on moist filter papers in a covered petri dish to imbibe water. To raise the seeds' moisture percentage to the desired level, the following formula was used:

$$\text{Weight required} = \frac{100 - \text{original seed moisture}}{100 - \text{desired seed moisture}} \times \text{initial seed weight}$$

When the original one gram of seeds imbibed enough moisture, and reached the weight shown by the above formula, it was sealed in an aluminium foil packet. It was then kept overnight in an incubator at 10°C. This was done the ensure that there is even distribution of moisture in the seed.

Initial tests were done to see the time required for different stages of deterioration. The seeds from guard row plants which had received medium levels of fertilizer during their growth period were used to find out the deterioration trend. The result of the experiment using three replicates of one gram seed and deteriorated at 45°C and 20% moisture for different periods is shown below.

Effect of deterioration period on mean germination percentage

Deterioration period (hours)	Mean Germination (percentage)
0	98.0
24	97.7
48	92.3
60	85.0
72	63.7
78	49.0
84	17.4
90	2.5
96	0.0

After the initial test, it was thought to deteriorate the seeds of the main experiments at 45°C and 20% moisture for 60 hours. After this period, the seeds had started showing rapid deterioration.

After the seeds were deteriorated for 60 hours, they were placed on moist filter paper (Whatman No. 182) in a petri dish for germination. The temperature of the incubator was maintained at 20^{o}C for the entire period of germination with 16 hours light.

The germination percentage after controlled deterioration was calculated and statistical analysis done for interpretation of results.

Slant test

This test is based on the work of Smith *et al.* (1973) who used it to determine the vigour of lettuce seedlings by measuring root length. It is basically the seedling exhaustion test which measures the root growth in darkness. They found that this test correlates very well with the vigour of the seed as evidenced by the subsequent size of lettuce head in the field.

100 seeds from each treatment were imbibed for three hours before they were placed on a blotter. Standard germination blotters were used to provide support for the seed and developing seedling and to provide a uniform and constant supply of moisture during germination and growth. Each blotter was precut into 9.5 x 13.5 cm rectangles and marked with a soft pencil line 2 cm down from the edge across the longer dimension to provide a guide for placing the seeds in a straight line. More parallel lines at an interval of 0.5 cm were drawn below the first line to faclitate the measurement of root length. The blotters were placed on support plates of plexiglass and moistened thoroughly. Using forceps, the seeds were placed radicle end down along the top pencil mark of each blotter. There were 4 replicates of 25 seeds. After positioning the seeds, the blotters supported

by plates were placed in a plastic growth box. 800 ml of distilled water was added in the box such that blotters touched the water, ensuring uniform capilliarity of water in the blotters. The blotters were held at an angle of 70^{o} from the horizontal by grooves cut in plexiglass rails in the bottom of the boxes. The boxes were then tightly fitted with plastic lids. They were then transferred to an unlit incubator. The temperature of the incubator was maintained at 25^{o}C. The lids of the boxes were lifted daily to inspect the seeds and also to allow exchange of air.

After 48, 72 and 96 hours, the blotters with their support were taken out, the root length of individual seedling measured along the marked pencil lines and returned to the incubator. No top length was measured.

The mean root length after 48, 72 and 96 hours was calculated and statistically analysed.

Electrical Conductivity Test

This is based on the work of Mathews and Powell (1980) and George and Atwood (1982). They had reported higher correaltion of electrical conductivity of leachate and emergence of pea, bean and cabbage seeds.

Seeds from each treatment were carefully checked through a table lens to ensure that only seeds with intact testas were used. Damaged seeds tend to have a very high leachate rate which may affect the result (Mathews and Powell, 1980).

Four replicates of 5 gm seeds from each treatment were placed in a beaker which had been cleaned, rinsed in deionized water and dried. 100 ml of de-ionized water at 20°C was measured and added to the beaker. Water was thoroughly stirred with a clean glass rod to ensure that the seeds were immersed in the water. The beaker was then covered tightly with a parafilm stretch to prevent evaporation and contamination by dust. They were then taken to an incubator and kept there for 24 hours at 20°C. A control beaker containing only de-ionized water was also placed in the incubator.

The soak water was then poured through a sieve into another beaker and the electrical conductivity reading of the soaked water was measured.

For measuring the electical Conductivity Model P310 electrical Conductivity Meter with a PE10 platinum black dip-type cell (Portland Electronics Ltd.) was used.

The reading of the water in the control beaker was also taken. Every precaution was taken to see that no variation in electrical conductivity reading takes place due to fluctuation in temperature or by contact with outside material which might affect the reading e.g. skin or uncleaned rod. At the end of each reading, the cell was thoroughly washed with deionized water.

For each replicate, the conductivity reading was expressed as $\mu S\ cm^{-1}\ g^{-1}$ after subtracting the reading of the control beaker. The result was statistically analysed.

Seedling Evaluation

The seedling evaluation test for seeds were conducted in a heated glasshouse with night temperature of $15^{o}C$ and day temperature of $20^{o}C$. Three replicates of 50 seeds from each treatment were sown at equal spacing in a plastic tray containing Levington potting compost. The seeds were covered with sieved Levington Universal Compost. It was firmly and uniformly pressed and watered. The trays were kept on a bench in the glass-house. Watering was done with a watering can. The trays were changed position to minimize the environmental effect.

After the seedlings started to emerge, daily count of emergins eedlings were recorded until there was no new emergence. Mean germination time (Ellis and Roberts, 1980) and germination rate (Maguire, 1962) were calculated. The following formula was used to calculate the mean germination time:-

$$\text{Mean germination time, days} = \frac{\Sigma(Dn)}{\Sigma n}$$

where

n = number of seeds which germinate on day D

D = number of days counted from the beginning of the germination test.

The most vigorous seeds take least mean time to germinate. Germination rate (Maguire, 1962) was calculated with the following formula:

$$\frac{\text{number of normal seedlings}}{\text{days to first count}} + \ldots\ldots + \frac{\text{number of normal seedlings}}{\text{days to final count}}$$

The most vigorous seeds are regarded as those which have the highest germination rate.

After the seedling had developed second true leaves (after 4 weeks), they were cut with a pair of scissors at soil surface level and fresh weight of the individual seedlings noted. Those seedlings which were one quarter or above of the largest seedling were regarded as normal (Tonkin, 1969).

The seedlings from each treatment were dried in an oven at 100°C for 48 hours and the mean dry weight was calculated.

Data were statistically analysed to interpret the differences in nutrient treatments.

RESULTS

RESULTS

Experiment 2

1. Seed Yield

The analysis of variance showed the mean seed yield per plant was not significantly affected by any of the treatments. The N, P and K main effect and N P K interaction effect are shown in Tables 2, 3, 4, 5 and 6.

Table 2. N, P and K main effects on mean seed yield per plant (g)

Nutrient level	Mean seed yield (g)	Level of significance
N_1	16.0	
N_2	15.2	Not significant (NS)
N_3	17.35	
P_1	16.8	
P_2	14.31	NS
P_3	17.5	
K_1	15.5	NS
K_2	16.9	

There was a very slight decrease in mean seed yield as the level of nitrogen increased from N_1 (50 kg/ha) to N_2 (100 kg/ha) Further increase in nitrogen level of N_3 (150 kg/ha) increased mean seed yield. However the differences in mean seed yield due to nitrogen levels was not significant. Levels of phosphorus have also not significantly affected the mean seed yield.

Although there is a slight mean seed yield increase due to increase in potassium levels from K_1 (50 kg/ha) to K_2 (100 kg/ha) the increase was not significant. The N, P and K main effect is shown in Fig. 1.

Table 3. The effect of N P K on mean seed yield (g)

		K_1	K_2
	P_1	13.06	11.38
N_1	P_2	14.18	19.29
	P_3	18.66	19.23
	P_1	17.08	27.42
N_2	P_2	7.61	7.37
	P_3	4.67	14.84
	P_1	12.98	18.50
N_3	P_2	20.51	16.95
	P_3	18.38	16.79

Level of significance - not significant.

N P K interactions had no significant effect.

Although there was a decreased mean seed yield at $N_2P_3K_1$, $N_2P_2K_1$ and $N_2P_2K_2$, the analysis of variance showed that the result was not significant.

Table 4. The effect of N P interactions on mean seed yield (g)

	P_1	P_2	P_3
N_1	12.35	16.74	18.94
N_2	22.25	7.49	16.00
N_3	15.74	18.73	17.58

Level of significance - not significant

Although the mean seed yield at N_2P_2 is lowest and at N_2P_1 is the highest, the analysis of variance showed that the interaction effect of N P was not significant.

Table 5. Effect of N K interactions on mean seed yield (g)

	K_1	K_2
N_1	15.3	16.7
N_2	14.0	16.5
N_3	17.3	17.4

Level of significance - not significant

NK interactions had no significant effect on the mean seed yield. Although the mean yield was higher at all combinations of nitrogen levels and K_2, it was not significant. N_3 at all K levels had also given higher but non-significant mean seed yields.

Table 6. The effect of P K interactions on mean seed yield (g)

	K_1	K_2
P_1	14.4	19.2
P_2	14.1	14.5
P_3	18.1	17.0

K_2 at all levels of P had generally given higher but not significant yield differences. P_3 at both K levels had also given higher mean seed yields, but the differences were not significant.

2. Seed Grade

The seeds from each treatment were graded into three size grades with the help of laboratory test sieves of various meshes. The size grades were:

A = above 2.00 mm

B = between 1.70 and 2.00 mm

C = between 1.40 and 1.70 mm

The percentages of seeds of different size grades were statistically analysed. The result is presented in Table 7.

Table 7. N, P and K main effects on seed size grades (%)

	A	B	C
N_1	24.8 a	55.9 a	19.3 a
N_2	24.0 a	53.6 a	22.4 a
N_3	24.7 a	57.2 a	18.1 a
P_1	24.5 a	53.3 a	22.2 a
P_2	23.8 a	54.9 a	21.3 a
P_3	25.2 a	58.6 a	16.2 a
K_1	23.7 a	57.8 a	18.5 a
K_2	25.2 a	53.4 a	21.4 a

The result showed that N, P and K had no significant effect on the different seed size grades. There were slightly higher percentages of grade A and B seeds produced at P_3 but the difference was not significant. There was no trend on the effect of N and K on different seed size grades. (Fig. 8).

3. 100 seed weight

The weight of 100 seeds was found to be affected by the application of N, P and K and all their interactions at 1% levels. The results are summarised in Tables 8, 9, 10, 11 and 12.

Table 8. N, P and K main effects on 100 seed weight

Nutrient level	100 seed weight (g) (means of 48)	Level of significance	5% LSD
N_1	.4547 a		
N_2	.4293 c	1%	.0042
N_3	.4421 b		
P_1	.4363 b		
P_2	.4371 b	1%	.0042
P_3	.4527 a		
K_1	.4445 a	1%	.0036
K_2	.4395 b		

Data followed by common letters (e.g. a, b, c) in different levels of a treatment is not significantly different.

From the table it was observed that the heaviest 100 seed weight was achieved at N_1 (50 kg/ha) followed by N_3 (150 kg/ha). The medium level of nitrogen (N_2, 100 kg/ha) reduced the 100 seed weight significantly. With phosphorus, the third level P_3 (150 kg/ha) had resulted in heaviest 100 seed weight. The 100 seed weight decreased with decrease in phosphorus level but P_2 and P_1 (75kg/ha and no phosphorus respectively) had similar 100 seed weight. 50 kg/ha of potash (K_1) resulted in heavier 100 seed weight than 100 kg/ha (K_2) (Fig. 9).

Table 9. The effect of N P interactions on 100 seed weight

100 seed weight (g) (means of 16)

	P_1	P_2	P_3
N_1	.4366 cd	.458 b	.4716 a
N_2	.4440 c	.4034 f	.4405 c
N_3	.4283 e	.4521 bc	.4460 c

Level of significance = 1%

5% LSD = .0075

Data followed by common letters are not significantly different.

The heaviest 100 seed weight was obtained at N_1P_3 followed by N_1P_2. The lightest 100 seed weight was obtained at N_2P_2.

Table 10. The effects of N K interactions on 100 seed weight

100 seed weight (g) (means of 24)

	K_1	K_2
N_1	.4753 a	.4340 c
N_2	.4361 c	.4225 d
N_3	.4223 d	.4620 b

Level of significance = 1% level

5% LSD = .0062

Data followed by common letters are not significantly different.

N_1K_1 had the heaviest 100 seed weight followed by N_3K_2. While N_3K_1 and N_2K_2 had the lightest 100 seed weight.

Table 11. The effect of P K interactions on 100 seed weight

100 seed weight(g) (mean of 24)

	K_1	K_2
P_1	.4457 b	.4269 d
P_2	.4398 c	.4343 c
P_3	.4491 b	.4573 a

Level of significance = 1%

5% LSD = .0062

Data followed by common letters are not significantly different.

The result showed that the heaviest 100 seed weight was obtained at P_3K_2 followed by P_3K_1 and P_1K_1. The lightest 100 seed weight was obtained at P_1K_2.

Table 12. The effects of N P K interactions on 100 seed weight

		100 seed weight (g) (Means of 8)	
		K_1	K_2
	P_1	.4804 b	.3927 i
N_1	P_2	.4514 d	.4603 c
	P_3	.4941 a	.4491 d
	P_1	.4525 d	.4355 e
N_2	P_2	.4395 e	.3672 j
	P_3	.4163 g	.4647 c
	P_1	.4042 h	.4524 d
N_3	P_2	.4286 f	.4755 b
	P_3	.4339 ef	.4581 c

Level of significance = 1 % level

5% LSD = .0107

Data followed by common letters are not significantly different.

The table shows that the heaviest 100 seed weight was produced using $N_1P_3K_1$ followed by $N_1P_1K_1$ and $N_3P_2K_2$. The lightest 100 seed weight was obtained at $N_2P_2K_2$.

4. Standard germination

The analysis of variance of standard germination of seeds showed that N, P and K main effect and their interactions had a significant effect on the mean seed germination percentage. The results are presented in Tables 13, 14, 15 and 16.

Table 13. N, P and K main effects on mean germination percentage.

Level of nutrients	Mean germination (%)	Level of significance	5% LSD
N_1	94.75 a		
N_2	92.29 b	1%	1.45
N_3	95.63 a		
P_1	92.33 b		
P_2	95.42 a	1%	1.45
P_3	94.92 a		
K_1	94.83 a	5%	1.36
K_2	93.61 b		

Numbers followed by common letters are not significantly different.

It is seen from the table that the first and third levels of nitrogen (N_1 and N_3) resulted in a significantly higher mean germination percentage than the medium level of nitrogen (N_2). The difference between the effect of N_3 and N_1 was not significant. Addition of phosphorus to the plant had significantly increased the germination percentage. Medium and high level of phosphorus (P_2 and P_3) had higher germination percentage over P_1, but the differences in the effect of P_2 and P_3 were small and non-significant. Higher levels of potassium (K_2) significantly reduced the germination percentage of seeds (Fig. 5).

Table 14. The effects of N P interactions on the mean germination percentage.

	P_1	P_2	P_3
N_1	94.25 b	95.88 ab	94.13 b
N_2	86.50 c	93.63 b	96.75 a
N_3	96.25 ab	96.75 a	93.88 b

Level of significance = 1% level

5% LSD = 2.50

Data followed by common letters are not significantly different.

The treatments N_3P_2 and N_2P_3 had the highest germination percentage followed by N_3P_1, N_1P_2. The lowest germination percentage was obtained at N_2P_1 (Fig. 6).

Table 15. The effect of N K interactions on mean germination percentage

	K_1	K_2
N_1	96.17	93.33
N_2	92.50	92.08
N_3	95.83	95.42

Level of significance - not significant

The N K interactions had no significant effect on the mean seed germination percentage. However, N_2 at both levels of K had a lower but not significant mean germination.

Table 16. The effect of P K interactions on the mean germination percentage

	K_1	K_2
P_1	93.67 b	91.00 c
P_2	94.75 ab	96.08 a
P_3	96.08 a	93.75 b

Level of significance = 5%

5% LSD = 2.04

Data followed by common letters are not significantly different.

The highest mean germination percentage was achieved at P_3K_1 and P_2K_2 followed by P_2K_1. The lowest mean germination percentage was obtained at P_1K_2 (Fig. 7).

5. Root length

The mean root length was measured after 72 hours of growth. The analysis of variance showed that the treatment had significant effect on mean root length. Potassium and nitrogen significantly increased the root length while phosphorus had no effect on mean root length. The results are presented in Table 17.

Table 17. N, P and K main effect on root length (cm)

Level of nutrient	Root length (cm)	Level of significance	5% LSD
N_1	2.936 b		
N_2	3.228 a	1%	0.155
N_3	3.372 a		
P_1	3.083 a		
P_2	3.203 a	NS	-
P_3	3.251 a		
K_1	3.094 b	1%	0.127
K_2	3.263 a		

Data followed by common letters in a nutrient treatment is not significantly different.

The third level of nitrogen(N_3) resulted in longer root length followed by N_2 and N_1. The difference between N_3 and N_2 was not significant.

$N_3 > N_2 > N_1$

Although there is a slight root length increase due to higher levels of phosphorus, the result was not significant.

$P_3 > P_2 > P_1$

The higher levels of potassium (K_2) resulted in longer root length over K_1

$K_2 > K_1$

The N, P and K main effect on root length measured after 72 hours of growth is shown in Fig. 7.

Table 18. The effect of N P interactions on mean root length (cm)

	P_1	P_2	P_3
N_1	2.656	3.086	3.067
N_2	3.267	3.154	3.264
N_3	3.325	3.368	3.424

Level of significance = N.S.

The N P interactions had no significant effect on the root length of cauliflower seeds. Although N_1P_1 had produced the shortest root and N_3P_3 the longest, there was no significant difference in the interaction effect of N P.

Table 19. The effect of N K interactions on mean root length (cm)

	K_1	K_2
N_1	2.800	3.072
N_2	3.172	3.284
N_3	3.311	3.434

Level of significance - N.S.

The interaction effect on N K had produced no significant differences in the root length. There is an increase in root length with increase in levels of nitrogen at both potassium levels but the differences were not significant statistically.

Table 20. The effect of P K interactions on mean root length (cm)

	K_1	K_2
P_1	2.958	3.207
P_2	3.061	3.344
P_3	3.264	3.239

Level of significance = N.S.

The P K interactions had no significant effect on the root length.

Table 21. The effect of N P K on mean root length (cm)

	P_1	2.365 c	2.947 b
N_1	P_2	2.983 b	3.188 ab
	P_3	3.053 b	3.080 b
	P_1	3.180 ab	3.353 ab
N_2	P_2	3.007 b	2.300 ab
	P_3	3.328 ab	3.200 ab
	P_1	3.330 ab	3.320 ab
N_3	P_2	3.192 ab	3.543 a
	P_3	3.410 ab	3.438 ab

Level of significance - 1%

5% LSD = .365

Data followed by common letters are not significantly different.

It can be observed that seeds from treatment $N_3P_2K_2$ had the longest roots and $N_1P_1K_1$ had the shortest. Generally there were longer roots at higher levels of nitrogen (N_3 followed by N_2) and Potassium (K_2).

6. Controlled deterioration

The analysis of variance showed that P significantly affected mean seed germination percentage after controlled deterioration at the 5% level. The interactions of N P, NK, P K and N P K also affected the mean germination percentage at the 1% level. These results are presented in Tables 22, 23, 24, 25, and 26.

Table 22. N, P and K main effects on mean germination percentage after controlled deterioration.

Nutrient level	Mean germination percentage	Level of significance	5% LSD
N_1	89.67 a		
N_2	89.33 a	N.S.	
N_3	90.78 a		
P_1	89.06 b		
P_2	89.17 b	5%	1.83
P_3	91.56 a		
K_1	89.52 a	N.S.	
K_2	90.33 a		

Figures for mean percentage followed by common letters are not significantly different.

As is seen from the table nitrogen or potassium had no significant effect on the mean germination percentage after controlled deterioration. Small root length increase at N_3 over N_2 and N_1, and at K_2 over K_1, was not of significance. Phosphorus at high level (P_3) had a small but significant increase in mean germination percentage over other levels of phosphorus. $P_3 > \underline{P_2 > P_1}$

Table 23. The effects of N P interactions on mean germination percentage after controlled deterioration.

	P_1	P_2	P_3
N_1	88.00 b	88.34 b	92.67 a
N_2	90.00 ab	86.50 b	91.50 ab
N_3	89.17 b	92.67 a	90.50 ab

Level of significance - 1% level

5% LSD = 3.10

Data followed by common letters are not significantly different.

The highest mean germination percentage after controlled deterioration was obtained at N_1P_3 and N_3P_2. The lowest mean germination percentage was shown by N_1P_1, N_1P_2 , N_2P_2 and N_3P_1.

Table 24. The effect of N K interactions on mean germination percentage after controlled deterioration.

	K_1	K_2
N_1	88.11 c	92.22 a
N_2	88.89 bc	89.78 b
N_3	92.56 a	89.00 bc

Level of significance - 1%

5% LSD = 2.53

Data followed by common letters are not significantly different.

The treatments N_3K_1 and N_1K_2 gave the highest mean germination percentage while N_1K_1 had the lowest germination percentage.

Table 25. The effect of P K interactions on the mean germination percentage after controlled deterioration.

	K_1	K_2
P_1	87.56 b	90.56 ab
P_2	90.67 ab	87.67 b
P_3	90.33 ab	92.78 a

Level of significance - 1% level

5% LSD = 2.53

Data followed by common letters are not significantly different.

It is evident from the data that treatment P_3K_2 had the highest mean germination percentage followed by P_2K_1, P_1K_2 and P_3K_1. The treatments P_2K_2 and P_1K_1 had the lowest mean germination percentage after controlled deterioration.

Table 26. The effect of N P K interactions on the mean germination percentage after controlled deterioration.

	P_1	81.67 c	94.33 a
N_1	P_2	88.67 b	88.00 bc
	P_3	91.00 ab	94.33 a
	P_1	86.33 bc	93.67 ab
N_2	P_2	89.33 b	83.67 c
	P_3	91.00 ab	92.00 ab
	P_1	94.67 a	83.67 c
N_3	P_2	94.00 a	91.33 ab
	P_3	89.00 b	92.00 ab

Level of significance - 1% level

5% LSD = 4.38

Data followed by common letters are not significantly different.

The highest mean germination percentage was achieved at $N_1P_1K_2$, $N_1P_3K_2$, $N_3P_1K_1$ and $N_3P_2K_1$ while the lowest was achieved at $N_1P_1K_1$ and $N_2P_2K_2$.

7. Electrical Conductivity Test

The analysis of variance showed that P and NP, NK, PK and NPK interactions significantly affected the conductivity of leachate from soaked seeds. They were all significant at the 1% level. The results are presented in Tables 27, 28, 29, 30 and 31.

Table 27. N, P and K main effects on conductivity of leachate

Nutrient level	Conductivity reading in μmho /gm seed	Level of Significance
N_1	23.339 a	
N_2	23.356 a	
N_3	22.956 a	
P_1	23.939 b	
P_2	22.900 a	1%
P_3	22.811 a	
K_1	23.056 a	
K_2	23.378 a	

5% LSD = .401

The number followed by similar letters within a treatment was not significantly different.

There was no nitrogen or potassium main effect on the conductivity of leachate. Addition of phosphorus had very significantly reduced the conductivity of leachate. There was no difference between the P_2 and P_3. Although the N_3 level also seems to produce low leachate conductivity but it was not significantly different from other levels of nitrogen treatment. N, P and K main effects on leachate conductivity is shown in Fig. 12.

Table 28. The effect of N P interactions on conductivity of leachate (μ mho /gm seed).

	P_1	P_2	P_3
N_1	24.184 cd	23.967 cd	21.867 a
N_2	23.533 c	21.900 a	24.634 d
N_3	24.100 cd	22.834 b	21.934 a

Significant at 1% level

5% LSD = .695

The treatments N_2P_2 and N_3P_3 had the lowest conductivity readings followed by N_3P_2. The highest conductivity reading was at N_2P_3 levels.

Table 29. The effect of N K interactions on conductivity of leachate (μ mho/gm seed)

	K_1	K_2
N_1	24.389 c	22.289 a
N_2	21.767 a	24.944 c
N_3	23.011 b	22.900 b

Significant at 1% level

5% LSD = .568

Data followed by common letters are not significantly different.

The treatments N_2K_1 and N_1K_2 had the lowest leachate conductivity reading while the treatment N_2K_2 and N_1K_1 had the highest leachate conductivity.

Table 30. The effect of P K interactions on conductivity of leachate (μmho/gm seed)

	K_1	K_2
P_1	24.400 d	23.578 c
P_2	22.233 a	23.567 c
P_3	22.633 ab	22.989 b

Significant at 1% level

5% LSD = .568

The data followed by common letters are not significantly different.

The treatment P_2K_1 had the lowest leachate conductivity reading while the treatment P_1K_1 had the highest.

Table 31. The effect of N P k interactions on conductivity of leachate (μmho./gm seed)

		K_1	K_2	Level of significance
	P_1	26.700 f	21.667 b	
N_1	P_2	23.833 d	24.100 de	
	P_3	22.633 c	21.100 b	
	P_1	22.833 c	24.233 de	
N_2	P_2	19.900 a	23.900 de	1%
	P_3	22.567 c	26.700 f	
	P_1	23.367 cd	24.833 e	
N_3	P_2	22.967 cd	22.700 c	
	P_3	22.700 c	21.167 b	

5% LSD = .983

Data followed by common letters are not significantly different.

The treatment $N_2P_2K_1$ had the lowest leachate conductivity reading followed by $N_3P_3K_2$ and $N_1P_1K_2$. The highest leached conductivity was obtained at $N_1P_1K_1$ and $N_2P_3K_2$.

8. Field emergence

The analysis of variance showed that phosphorus application had significant effect on the field emergence of seedling at the 1% level. Theinteractions of N with P or K and N P K interactions effects were significant at the 5% level. The results are shown in Tables 32, 33, 34, 35 and 36.

Table 32. N, P and K main effects on percentage field emergence

Nutrients	Field emergence (%)	Level of significance	5% LSD
N_1	85.5 a		
N_2	86.2 a	N.S.	-
N_3	85.6 a		
P_1	82.2 b		
P_2	86.9 a	1%	3.65
P_3	88.3 a		
K_1	86.8 a	N.S.	-
K_2	84.8 a		

Numbers followed by a common letter for each nutrient are not significantly different.

There was a significant increase in the percentage of seedling field emergence from P_1 to P_2. There was further increase in the field emergence from P_2 to P_3 but this difference was not significant.

Nitrogen did not affect field emergence. There was a small but non-significant decrease in field emergence with the K_2 potassium level (Fig. 13).

Table 33. The effect of N P interactions on percentage field emergence

	P_1	P_2	P_3
N_1	82.75 b	86.75 ab	87.0 ab
N_2	83.25 b	87.25 ab	88.1 ab
N_3	80.6 b	86.6 ab	89.6 a

Level of significance - 5%

5% LSD = 6.32

The data followed by a common letter are not significantly different.

The treatment N_3P_3 had shown the highest percentage field emergence and N_3P_1 the lowest. All other treatments except N_3P_3 were not significantly different from N_3P_1 (Fig. 14).

Table 34. The effect of N K interactions on percentage field emergence

N_1	88.75 a	82.25 b
N_2	87.75 a	84.67 ab
N_3	83.83 ab	87.42 a

Significance - 5% level

5% LSD = 5.16

Data followed by a common letter are not significantly different.

Treatments N_1K_1 followed by N_2K_1 and N_3K_2 had higher field emergence while N_1K_2 had the lowest. Other treatments were not significantly different (Fig. 15).

Table 35. The effect of P K interactions on percentage field emergence

	K_1	K_2
P_1	82.58	81.83
P_2	86.75	87.00
P_3	91.00	85.00

Significance - N.S.

The interaction effect of PK was not significant. The general trend was that there is an increase in field emergence with an increase in phosphorus levels at both K levels except at P_3K_2 which is slightly but non-significantly lower than at P_2K_2.

Table 36. The effect of N P K interactions on percentage field emergence

		K_1	K_2
	P_1	86.25 ab	79.25 b
N_1	P_2	87.50 ab	86.00 ab
	P_3	92.50 a	81.50 b
	P_1	83.25 b	83.25 b
N_2	P_2	92.25 a	82.25 b
	P_3	87.75 ab	88.50 ab

Table 36. continued

	P_1	78.25 b	83.00 b
N_3	P_2	80.50 b	92.75 a
	P_3	92.75 a	86.50 ab

Significance = 5%level

5% LSD = 8.94

Data followed by a common letter are not significantly different.

The treatments $N_3P_3K_1$ and $N_3P_2K_2$ followed by $N_1P_3K_1$ and $N_2P_2K_1$ had the highest percentage and the treatments $N_3P_1K_1$ and $N_1P_1K_2$ the lowest percentage field emergence (Fig. 16).

9. Seedling emergence (in field soil)

The analysis of variance showed that only N P and N K interactions had a significant effect on the seedling emergence percentage in field soil under glasshouse conditions. The N, P and K main effect had no significant effect on percentage emergence of seedlings in field soil. The results are presented in Tables 37, 38, 39, and 40.

Table 37. Seedling emergence percentage in relation to N P K effect in field soil.

		K_1	K_2
	P_1	89.57 ab	88.33 ab
N_1	P_2	89.80 ab	91.23 a
	P_3	90.00 a	93.23 a
	P_1	90.23 a	93.43 a
N_2	P_2	89.53 ab	87.70 ab
	P_3	89.23 ab	79.77 b
	P_1	92.33 a	89.97 ab
N_3	P_2	92.20 a	82.67 b
	P_3	91.47 a	90.33 ab

Level of significance = 5% level

5% LSD = 7.32

Data followed by common letters are not significantly different

The treatments $N_2P_1K_2$, $N_1P_3K_2$ had the highest emergence percentage. Treatments $N_2P_3K_2$ and $N_3P_2K_2$ had significantly lower emergence percentage.

Table 38. N, P and K main effect on seedling emergence percentage in field soil

Level of nutrients	Emergence percentage	Level of significance
N_1	90.36	
N_2	88.32	N.S.
N_3	89.31	
P_1	90.13	
P_2	88.86	N.S.
P_3	89.01	
K_1	90.47	N.S.
K_2	88.19	

The N, P and K main effect did not show a significant difference in percentage seedling emergence in field soil when tested in the glasshouse.

Table 39. The effect of N P interactions on seedling emergence percentage in field soil

	P_1	P_2	P_3
N_1	88.95 ab	90.52 a	91.62 a
N_2	91.83 a	88.62 ab	84.50 b
N_3	89.60 ab	87.43 ab	90.90 a

Level of significance = 5%

5% LSD = 5.18

Data followed by common letters are not significantly different.

Treatment N_2P_1 had the highest seedling emergence. All other treatments were similar to N_2P_1 except N_2P_3 which had significantly lower seedling emergence percentage.

Table 40 The effect of N K interactions on seedling emergence in field soil

	K_1	K_2
N_1	89.79 ab	90.93 ab
N_2	89.67 ab	86.97 b
N_3	91.97 a	86.66 b

Level of significance - 5% level

5% LSD = 4.23

Data followed by a common letter are not significantly different.

The treatment N_3K_1 had the highest seedling emergence percentage in soil but it was not significantly different from other treatments except N_2K_2 and N_3K_2 which had significantly lower emergence percentages.

10. Seedling Emergence (peat)

The analysis of variance showed that only K had significant effect on the percentage of seedling emergence in peat. The results are presented in Tables 41 and 42.

Table 41. Seedling emergence percentage (peat) in relation to NPK effect

		K_1	K_2
	P_1	92.00 a	87.00 ab
N_1	P_2	90.33 a	93.00 a
	P_3	95.00 a	94.67 a
	P_1	93.67 a	92.67 a
N_2	P_2	95.33 a	89.67 a
	P_3	95.33 a	73.00 b
	P_1	95.67 a	88.00 ab
N_3	P_2	92.00 a	81.00 ab
	P_3	93.67 a	94.00 a

Level of significance - 5% level

5% LSD = 16.03

Data followed by a common letter are not significantly different.

Only treatment $N_2P_3K_2$ had significantly lower emergence percentage. All other treatments were similar in their performance.

Table 42. N, P and K main effects on percentage seedling emergence in peat

Level of nutrients	emergence percentage	Level of significance	5% LSD
N_1	92.00 a		
N_2	89.95 a	N.S.	
N_3	90.84 a		
P_1	91.50 a		
P_2	90.22 a	N.S.	
P_3	91.06 a		
K_1	93.67 a		
K_2	88.19 b	5%	5.35

Data followed by a common letter in a treatment were not significantly different.

It is evident from the table that N and P had no significant effect on seedling emergence percentage in peat. Although there is a slightly higher emergence percentage at lower level of nitrogen (N_1) but the difference did not reach significance level. Only the lower level of potassium (K_1) had produced seeds which had superior emergence over higher level of potassium (K_2).

11. Seedling Evaluation

a. Mean time to emergence (days)

The analysis of variance showed that P had a significant effect on the mean time to emergence at 1% level and N and N P at the 5% level. K had no significant effect on the mean time to emergence. The results are presented in Tables 43, 44 and 45.

Table 43. N, P and K main effects on mean time to emergence (days)

Nutrient level	Time to emergence	Level of significance	5% LSD
N_1	4.1756 b		
N_2	4.0978 a	5%	.0619
N_3	4.1822 b		
P_1	4.2272 c		
P_2	4.0756 a	1%	.0619
P_3	4.1528 b		
K_1	4.164 a	N.S.	
K_2	4.140 a		

Data followed by a common letter in each treatment are not significantly different.

Seeds produced on plants receiving the medium level of nitrogen (N_2) took the least mean days to emergence in peat. Seeds produced at N_1 and N_3 had taken significnatly more mean days to emergence than N_2 but both N_1 and N_3 had similar performance. $N_2 \leftarrow \underline{N_1 \leftarrow N_3}$.

The medium level of phosphorus (P_2) had also taken the least mean days to emergence followed by seeds produced at P_3 and P_1. All three levels of phosphorus had produced seeds which had significantly different mean days to emergence. $P_2 \leftarrow P_3 \leftarrow P_1$.

Potassium had no effect on seeds and both levels produced seeds which had similar mean days to emergence.

Table 44. The effect of N P interactions on mean time to emergence (days)

N_1	4.3300 b	4.0767 a	4.1200 ab
N_2	4.1317 ab	4.0433 a	4.1183 ab
N_3	4.2200 b	4.1067 a	4.2200 b

Level of significance - 5%

5% LSD = .1071

Data followed by common letters are not significantly different.

The data shows that seeds produced at N_2P_2, N_1P_2 and N_3P_2 had taken the least mean days to emergence while the seeds produced by N_1P_1, N_3P_1 and N_3P_3 had taken significantly more mean days to emergence. Data also indicates that P_2 at all combinations of N had taken less mean time to emergence. N had no such trend.

Table 45. The effect of N P K interactions on mean time to emergence (days)

	P_1	4.2300 bc	4.4300 c
N_1	P_2	4.1333 ab	4.0200 a
	P_3	4.1700 ab	4.0700 ab
	P_1	4.1733 b	4.0900 ab
N_2	P_2	4.0600 ab	4.0267 ab
	P_3	4.1667 ab	4.0700 ab
	P_1	4.2100 b	4.2300 b
N_3	P_2	4.0733 ab	4.1400 ab
	P_3	4.2600 b	4.1800 b

Level of significance - 1% level

5% LSD = .1516

Data followed by common letters are not significantly different.

The treatment combinations $N_1P_2K_2$ had produced seeds which had the least mean days to emergence while $N_1P_1K_2$ and $N_1P_1K_1$ took significantly more mean days to emergence in peat.

b. Rate of seedling emergence

The rate of seedling emergence was calculated on the basis of Maguire (1962). The analysis of variance showed that N and P main effect and N P K interactions effect was significant at the 1% level while K and N P, N K and P K interactions had no significant effect on the rate of emergence. The results are presented in Tables 46 and 47.

Table 46. N, P and K main effect on rate of emergence

Nutrient level	Rate	Level of significance	5% LSD
N_1	26.89 b		
N_2	28.08 a	1%	.69
N_3	27.26 b		
P_1	26.41 b		
P_2	28.14 a	1%	.69
P_3	27.68 a		
K_1	27.64 a	N.S.	
K_2	26.87 a		

Data followed by a common letter are not significantly different.

The seeds produced at the medium level of nitrogen (N_2) had a significantly higher rate of emergence followed by N_3 and N_1. The N_3 and N_1 seeds were similar in performance. The trend was $N_2 \nless \underline{N_3 \nless N_1}$.

Seeds produced at the medium level of phosphorus (P_2) and high level of phosphorus (P_3) had significantly higher rate of emergence than at P_1. Performance of P_2 and P_3 was not significantly different. $\underline{P_2 \rightarrow P_3} \rightarrow P_1$.

Although seeds from the lower level of potassium had a slightly higher rate of emergence, the statistical analysis showed no significant difference between two levels of potassium.

Table 47. The effect of N P K interactions on rate of emergence

		K_1	K_2
	P_1	26.37 b	24.03 c
N_1	P_2	27.57 ab	27.97 ab
	P_3	27.00 ab	28.40 a
	P_1	27.67 ab	28.10 ab
N_2	P_2	28.40 a	28.63 a
	P_3	27.77 ab	27.87 ab
	P_1	26.67 b	25.63 bc
N_3	P_2	28.57 a	27.63 ab
	P_3	27.70 ab	27.33 ab

Significance level - 5% level

5% LSD - 1.69

Data followed by a common letter are not significantly different.

The results show that the seeds produced at $N_3P_2K_1$, $N_2P_2K_2$, $N_2P_2K_1$ and $N_1P_3K_2$ had the highest rate of emergence while seeds at $N_1P_1K_2$ had the lowest rate of emergence.

c. Normal vigorous seedling

The seedlings which were 25% or above by weight of the heaviest seedling were considered normal vigours seedlings (Tonkin, 1969). The N, P and K main effect and the N P, N K, P K interaction effects had shown no significant differences in producing normal vigorous seedlings. However N P K interactions were significant at the 1% level. N, P and K main effects and N P K interaction effects are shown in Tables 48 and 49.

Table 48. N, P and K main effect on production of normal vigorous seedlings

Level of nutrient	% Normal vigorous seedlings	Level of significance
N_1	96.76	
N_2	97.09	N.S.
N_3	96.41	
P_1	95.37	
P_2	97.67	N.S.
P_3	97.22	
K_1	96.52	N.S.
K_2	96.99	

None of the treatments had a significant effect on production of normal seedlings. However, there is a clear indication that addition of phosphorus resulted in a higher but not significant increase in normal vigorous seedlings.

Table 49. The N P K interaction effects on production of normal vigorous seedlings (percentages)

		K_1	K_2
	P_1	97.23 ab	92.37 b
N_1	P_2	97.90 ab	97.90 ab
	P_3	95.83 ab	99.30 a
	P_1	93.73 b	98.60 a
N_2	P_2	98.60 a	97.90 ab
	P_3	97.90 ab	95.83 ab
	P_1	93.07 b	97.23 ab
N_3	P_2	98.60 a	95.13 ab
	P_3	95.83 ab	98.60 a

Level of significance - 1% level

5% LSD = 4.75

Data followed by a common letter are not significantly different.

It is seen from the table that the treatment combinations $N_1P_3K_2$ had the highest percentage of normal vigorous seedlings closely followed by $N_2P_1K_2$, $N_2P_2K_1$, $N_3P_2K_1$ and $N_3P_3K_2$. The treatments which had produced significantly lower percentages of normal vigorous seedlings were $N_1P_1K_2$, $N_2P_1K_1$ and $N_3P_1K_1$. Other treatment combinations were not significantly different from those treatment combinations which produced higher or lower normal vigorous seedlings. The N P K interaction effects on production of normal seedling is presented in Fig. 17.

12. Mean seedling dry weight

The mean seedling dry weight is expressed as the mean weight of seedlings dried at 100°C for 48 hours. The analysis of variance showed that neither N, P and K main effects or their interactions had any significant effect on the mean seedling dry weight. Tables 50 and 51 show the effect of treatments on mean seedling dry weight.

Table 50. Mean seedling dry weight (g) in relation to N P K

		K_1	K_2
	P_1	0.0479	0.0463
N_1	P_2	0.0569	0.0452
	P_3	0.0501	0.0525
	P_1	0.0532	0.0527
N_2	P_2	0.0483	0.0506
	P_3	0.0503	0.0482
	P_1	0.0466	0.0506
N_3	P_2	0.0495	0.0514
	P_3	0.0538	0.0487

Level of significance - not significant

Although it can be seen from the table that some treatments had slightly higher mean seedling dry weight, they were not significantly different from those treatments which had lower mean seedling dry weight.

Table 51. The N, P and K main effect on mean seedling dry weight

Nutrient level	Mean dry weight (g)	Level of significance
N_1	0.0498	
N_2	0.0506	N.S.
N_3	0.0501	
P_1	0.0495	
P_2	0.0503	N.S.
P_3	0.0506	
K_1	0.0507	N.S.
K_2	0.0496	

It can be seen from the table that none of the main treatments had significant effect on the mean seedling dry weight.

Experiment 3

Effect of nitrogen on cauliflower seed

1. Dry matter

The analysis of variance showed that levels of nitrogen did not significantly affect the mean dry matter of the mother plants. The result is shown in Table 52.

Table 52. The effect of nitrogen on mean dry matter

Level of nutrients	Mean dry matter (g)	Level of significance
N_1	111.06	
N_2	131.47	Not significant
N_3	149.37	
N_4	157.71	

It can be observed that increasing the level of nitrogen from N_1 (50 kg/ha) to N_4 (350 kg/ha) has resulted in gradual increase in mean dry matter content of the cauliflower plant. However, the increase was not significant.

2. Seed Yield

There was a slight but not significant increase in the mean seed yield of cauliflower with the increase in nitrogen levels from N_1 (50 kg/ha) to N_2(150 kg/ha) and N_3 (250 kg/ha). Further increase in levels of nitrogen to N_4 (350 kg/ha) resulted in slight and non-significant decrease in mean seed yield. The result is presented in Table 53 and Fig. 2

Table 53. The effect of nitrogen on mean seed yield

Nutrient level	Mean seed yield (g)	Level of significance
N_1	35.70	
N_2	37.30	Not significant
N_3	41.70	
N_4	38.70	

3. Distribution of seeds into size grades

The cleaned seeds were divided into three groups, i.e. large (A., above 2.00 mm), B (medium) between 1.70 and 2.00 mm) and C (small) below 1.70 mm). The grading was done with laboratory test sieves of the appropriate sized mesh. The distribution of different size grades of seeds at different levels of nitrogen is presented in Table 54.

Table 54. The effect of nitrogen on distribution of seeds into different size grades (%)

Level of N	A	B	C
N_1	3.91 c	81.23 a	14.86 a
N_2	6.69 b	84.37 a	8.94 c
N_3	4.25 c	84.99 a	10.76 bc
N_4	13.28 a	74.58 a	12.14 b
Level of significance	1%	N.S.	1%
5% LSD	1.29	-	2.53

Data followed by a common letter in a column are not significantly different.

It is seen from the table that the percentage of large size seed (grade A) increased with increase in nitrogen level except at the third level of nitrogen (N_3) where the percentage of grade A seeds declined. The effect of nitrogen level on grade A seeds were in the following order $N_4 \leftarrow N_2 \leftarrow \underline{N_3 \leftarrow N_1}$.

Nutrient levels underscored by the same line are not significantly different.

There was no significant effect of nitrogen levels on the percentage distribution of grade B (1.7 mm to 2.00 mm) seeds.

There were significantly higher percentage of grade C (below 1.7 mm) seeds at the N_1 level followed by at N_4 level. The lowest percentage of grade C seeds were at the N_2 level followed by the N_3. N_1 $\underline{N_4 \quad N_3} \quad N_2$

Seed Quality Tests

The seeds produced at the four nitrogen levels were divided into (A), large, above 2.00 mm, (B) medium, between 1.7 and 2.00 mm, (C) small, between 1.4 and 1.7 mm and (D) ungraded seeds. The combinations of levels of nitrogen and seed size grades were tested for quality.

1. 100 seed weight

Nitrogen, seed grades and their interactions had very highly significant effect on the 100 seed weight. The result is presented in Table 55.

Table 55. The nitrogen and seed grade main effect on 100 seed weight.

Levels of treatment	100 seed weight (g)	Level of significance	5% LSD
N_1	0.40805 c		
N_2	0.42555 a	.1%	.0035
N_3	0.41947 b		
N_4	0.42167 b		
A	0.51574 a		
B	0.41928 b	.1%	.0035
C	0.31730 c		
D	0.42241 b		

Numbers followed by a common letter are not significantly different.

There was a significant increase in the 100 seed weight with nitrogen level increase from N_1 to N_2. Further increases to N_3 and N_4 resulted in a decrease in 100 seed weight. The 100 seed weight at N_3 and N_4 levels were not significantly different. $N_2 \leftarrow \underline{N_4 \leftarrow N_3} \leftarrow N_1$

There was a highly significant increase in 100 seed weight as the seed grades increased from small (C) to medium (B) and large (A). The 100 seed weight of ungraded seeds (D) was similar to medium (B) grade seeds.

Table 56. The effect of nitrogen and seed grade interaction on 100 seed weight (g)

	A	B	C	D
N_1	0.49784 c	0.40134 f	0.31299 h	0.42004 e
N_2	0.52029 b	0.43104 d	0.31633 gh	0.43456 d
N_3	0.51490 b	0.42456 de	0.32316 g	0.41524 e
N_4	0.52993 a	0.42019 e	0.31674 gh	0.41981 e

Level of significance - 1% level

5% LSD = 0.0071

Data followed by a common letter is not significantly different.

The data shows that the highest 100 seed weight was obtained at N_4A followed by that at N_2A and N_3A. The lowest seed weight was obtained at N_1C.

2. Standard germination

The analysis of variance showed that neither nitrogen (N) nor seed grades had a significant effect on the standard germination percentage. The data in presented in Table 54.

Table 57. The effect of nitrogen and seed grades on germination percentage

Treatment	Germination %	Level of significance
N_1	93.5	
N_2	97.5	N.S.
N_3	96.5	
N_4	95.75	
A	98.0	

Table 57 continued

Treatment	Germination %	Level of significance
B	96.5	N.S.
C	92.5	
D	96.5	

Nitrogen had no significant effect on the standard germination percentage of seeds. However, there is an indication that as the level of nitrogen increased from N_1 to N_2, there was a small but not significant increase in percentage germination. However a further increase resulted in small but not significant decrease in seed germination percentage.

Similarly the seed grade did not show a significant difference. There is an indication that with the seed size increase from C (below 1.7 mm) to B (1.7 - 2.00 mm) and A (above 2.00 mm), there was a slight trend towards a higher germination percentage. However, the increase is small and not significant. Ungraded seed (D) had similar germination percentage to B grade seeds.

3. Root length

Seeds from four levels of nitrogen and four seed grades were germinated in dark at 70^{o} angle and the mean root length measured after 48, 72 and 96 hours. An analysis of variance showed that after 48 hours of germination, nitrogen (N), seed grade (G) and nitrogen grade (N G) interactions were significant at the 1% level. The reading taken after 72 hours showed that seed grade (G) and nitrogen grade (N G) interactions were significant at the 1% level, nitrogen effect was significant at the 5% level. But after 96 hours there was no significant difference either due to N and G main effects or their interaction effects (Figs. 15 and 16).

a. After 48 hours

Table 58. Nitrogen and seed grade main effect on mean root length (cm) after 48 hours.

Treatment	Root length (cm)	Level of significance	5% LSD
N_1	0.79 b		
N_2	0.93 a	1%	.08
N_3	0.82 b		
N_4	0.86 ab		
A	0.77 b		
B	0.94 a	1%	.08
C	0.86 ab		
D	0.84 b		

Numbers followed by a common letter in each treatment are not significantly different.

The result showed N_2 followed by N_4 had longer roots. N_1 had the shortest root. The root length at N_1, N_3 and N_4 was not significantly different.

Similarly B grade seeds followed by C grade had the longer roots. The roots at A, D and C were not significantly different. B ← C ← D ← A

Table 59. The effect of nitrogen and seed grade interactions on root length (cm) after 48 hours

	A	B	C	D
N_1	0.65 d	0.84 bc	0.91 bc	0.76 c
N_2	0.83 c	0.97 bc	0.91 bc	1.0 b
N_3	0.78 cd	0.83 c	0.82 c	0.84 bc
N_4	0.82 c	1.23 a	0.80 cd	0.74 cd

Level of significance - 1% level

5% LSD = 0 .153

The treatments N_4B produced the longest root after 48 hours of germination. N_1A had the shortest root length.

b. Root length after 72 hours

The root length measured after 72 hours showed that the effect of nitrogen was significant at the 5% level while the grade effect on root length was significant at the 1% level. The result is shown in Table 60.

Table 60. The effect of nitrogen and seed grade on root length after 72 hours

	A	B	C	D
N_1	1.95 c	2.22 bc	2.50 b	2.11 c
N_2	2.34 bc	2.44 bc	2.47 bc	2.43 bc
N_3	2.16 c	2.35 bc	2.21 c	2.50 b
N_4	2.26 bc	2.82 a	2.08 c	2.12 c

Level of significance - 1% level

5% LSD = 0.28

The treatment N_4B had the longest root followed by N_3D and N_1C. Shortest root length was obtained at N_1A. Other treatments were not significantly different from N_1A.

Table 61. Nitrogen and seed grade main effect on root length after 72 hours

Treatment	Root length (cm)	Level of significance	5% LSD
N_1	2.20 b		
N_2	2.42 a	5%	0 .14
N_3	2.31 ab		
N_4	2.32 ab		
A	2.18 b		
B	2.46 a		
C	2.31 b	1%	0 .14
D	2.29 b		

Data followed by a common letter in each treatment are not significantly different.

It is seen from the table that treatment N_2 had the longest roots after 72 hours of growth while N_1 had the shortest roots. Treatments N_3 and N_4 were similar and not significantly different either from N_2 or N_1, such that $\underline{N_2 + N_4 + N_3} + N_1$

B grade seed had produced significantly longer roots than seeds from the other grades. All other seed grades were not statistically different in their performance.

c. Root length after 96 hours

Neither nitrogen nor seed grade had significant effect on root length after 96 hours of growth. The nitrogen and seed grade effects are shown in Table 61.

Table 62. Nitrogen and seed grade main effect on root length after 96 hours

Treatment	Root length (cm)	Level of significance
N_1	4.84	
N_2	4.71	N.S.
N_3	4.83	
N_4	4.92	
A	4.82	
B	4.92	N.S.
C	4.71	
D	4.86	

It can be seen from the table that none of the treatments had a significant effect on root length. Although the treatment effect is not significant, N_4 had a slightly longer root length than the other nitrogen levels. Similarly B grade seeds had slightly longer roots than the other seed grades.

4. Normal vigorous seedling

The seedlings which were 25% or more above of the heaviest seedling were regarded as normal vigorous seedlings. The percentages of normal seedlings were transformed into angles and the data were subjected to analysis of variance. The nitrogen treatment and nitrogen seed grade interaction had not affected the incidence of normal seedlings but seed grade had a significant effect on the production of normal seedling at 1%. The results are presented in Table 63.

Table 63. Nitrogen and seed grade main effect on production of normal seedlings

Treatments	Normal seedlings	Level of significance	5% LSD
N_1	75.24 a		
N_2	76.49 a	N.S.	-
N_3	78.98 a		
N_4	77.39 a		
A	80.41 a		
B	77.82 a	1%	4.34
C	77.52 b		
D	77.26 a		

Numbers followed by a common letter in each treatment are not significantly different.

Although there is a very slight increase in numbers of normal seedlings with an increase in nitrogen level, the result did not reach significance level. A, B and D grade seed produced significantly higher normal seedling than C (small) grade seeds. The normal seedlings produced at A, B and D were not significantly different. A ← B ← D ← C

5. Field emergence

The percentages of field emergence were transformed into angles and statistically analysed. From the analysis of variance it was found that the treatments had a significant effect on field emergence. Seed grades showed significant differences at 1% level while nitrogen had no significant effect. The results are shown in Tables 64, and 64a

Table 64. The effect of nitrogen and seed grade on field emergence percentage

	A	B	C	D
N_1	66.76 ab	67.53 ab	57.47 b	62.76 b
N_2	71.25 a	66.73 ab	58.27 b	66.26 ab
N_3	69.96 ab	67.92 ab	58.52 b	63.60 b
N_4	69.98 ab	69.64 ab	60.58 b	69.11 ab

Level of significance - 1%

5% LSD = 6.85

Data followed by a common letter were not significantly different.

Treatment N_2A had the highest percentage field emergence. The treatments N_3D, N_1D and combinations of C with all levels of nitrogen had significantly lower percentage field emergence than N_2A. Other treatments were not significantly different.

Table 64a. Nitrogen and grade main effect on percentage field emergence

	emergence	Level of significance	5% LSD
N_1	63.71 a		
N_2	65.63 a	N.S.	
N_3	64.99 a		
N_4	67.33 a		
A	69.49 a		
B	67.95 ab	1%	3.43
C	58.91 c		
D	65.43 b		

Although there is a very slight increase in the percentage field emergence with increase in nitrogen level, the result was not significant. A and B grade seeds had the highest seedling emergence. Ungraded seeds (D) were similar in performance to B seeds. C grade seeds had significantly lower field emergence.

6. Controlled deterioration

Seed germination percentages after controlled deterioration were transformed into angles and the data analysed statistically. Nitrogen had produced no significant differences in germination of controlled deteriorated seeds. The result is shown in Table 65.

Table 65. The effect of nitrogen on germination after controlled deterioration

	Germination %	Level of significance
N_1	60.4	
N_2	60.5	N.S.
N_3	61.7	
N_4	61.1	

It is seen from the table that the nitrogen level had no effect on the germination of seeds after controlled deterioration.

7. Curd yield

Effect of mother plant nutrition with nitrogen and different seed grades on curd yield of the progeny showed that neither mother plant nutrition nor graded seeds had significant effect on mean curd yield of cauliflower. The mother plant nutrition and seed grade effect is shown in Tables 66 and 67.

Table 66. The effect of mother plant nutrition with nitrogen and graded seed on cauliflower curd yield.

	Mean curd yield (g)	Level of significance
N_1	440.25	
N_2	413.67	N.S
N_3	434.25	
N_4	446.00	

Table 66 continued

	Mean curd yield (g)	Level of significance
A	419.75	
B	450.0	N.S
C	388.75	
D	475.67	

As can be seen from Table 66 mother plant nutrition with nitrogen had no significant effect on curd yield.

Similarly, the seed grade did not show significant differences in yield. However, the data suggests that the yield from C grade seed was low, although not significant. Ungraded seed (D) had a slightly higher mean curd yield.

Table 67. The effect of nitrogen and graded seed on mean curd yield (g)

	A	B	C	D
N_1	392.33	497.67	436.33	434.67
N_2	290.33	482.00	512.00	370.33
N_3	592.33	374.00	276.33	494.33
N_4	404.00	446.33	330.33	603.33

Level of significance - Not significant

Analysis of variance showed that the differences between treatments were not significant.

Experiment 4

The effect of phosphorus on cauliflower seed

1. Seed yield

There was no significant effect of phosphorus on seed yield of cauliflower. The mean seed yield is shown in Table 68.

Table 68. The effect of phosphorus on mean seed yield

Level of nutrients	Mean seed yield (g)	Level of significance
P_1	29.30	
P_2	28.70	N.S.
P_3	30.50	
P_4	31.00	

It is seen from the table that increasing the level of phosphorus from P_1 (50 kg/ha) to P_2 (100 kg/ha), P_3 (150 kg/ha) and P_4 (200 kg/ha) had no consistent effect on seed yield.

2. Distribution of seeds into size grades (%)

Seeds were divided into (A) large(above 2.00 mm),(B) medium (between 1.7 and 2.00mm) and (C) small (below 1.70 mm) grades and the percentage in different grades ascertained. Table 69 shows the percentage distribution of seeds into various grades.

Table 69. Distribution of seeds into the three grades (%)

	A	B	C
P_1	3.56 b	75.41 b	21.03 a
P_2	2.50 b	81.37 ab	16.13 b
P_3	6.42 a	87.13 a	6.45 d
P_4	3.55 b	85.77 a	11.18 c
Level of significance -			
	1%	5%	1%
5% LSD	2.85	8.05	3.55

There was a significantly higher percentage of grade A seeds at P_3. The treatments P_1, P_2 and P_4 were not significantly different in producing A grade seeds. B grade seed also had high percentage at P_3. However, B grade seeds produced at P_4 and P_2 were not significantly different from that at P_3. P_1 had produced lower percentage of B grade seeds followed by that at P_2. P_3 had the lowest grade C seeds. There were consistently lower percentage C grade seeds at higher phosphorus levels. Percentage of C grade seeds were in the following order: $P_1 > P_2 > P_4 > P_3$.

Seed quality tests

The seeds produced at four levels of phosphorus were divided into(A)large (above 2.00 mm), (B) medium (between 2.00 and 1.70 mm),(C) small (below 1.70 mm) and (D) ungraded seeds. Combinations of levels of phosphorus and seed grades were tested for seed quality.

1. <u>100 seed weight</u>

Phosphorus, seed grades and their interactions had a very highly significant effect on 100 seed weight. The result is presented in Tables 70 and 71.

Table 70. The phosphorus and seed grade main effect on 100 seed weight

Treatment	100 seed weight (g)	Level of significance	5% LSD
P_1	0.39350 a		
P_2	0.38728 b	1%	0.0049
P_3	0.39648 a		
P_4	0.38895 b		
A	0.48635 a		
B	0.39169 b	1%	0.0049
C	0.29431 c		
D	0.39386 b		

Number followed by a common letter in each treatment are not significantly different.

The third level of phosphorus (P_3) followed by the first level (P_1) had the heaviest 100 seed weight. Effect of P_3 and P_1 on seed weight was not significantly different. The second (P_2) and fourth (P_4) levels of phosphorus resulted in 100 seed weights which were higher than at P_3 and P_1. However, the effect of P_2 and P_4 was not significantly different.

different. $\underline{P_3 \leftarrow P_1} \leftarrow \underline{P_4 \leftarrow P_2}$

There was a highly significant increase in 100 seed weight as the seed size increased from small (C) to medium (B) and large (A). The 100 seed weight of mixed seeds (D) was similar to medium (B) grade seed.

Table 71. The effect of phosphorus and seed grade interactions on 100 seed weight

	A	B	C	D
P_1	0.49389 a	0.39644 d	0.29278 f	0.39091 de
P_2	0.48081 b	0.39255 de	0.29487 f	0.39090 e
P_3	0.48859 ab	0.39145 de	0.29404 f	0.41185 c
P_4	0.48211 b	0.38634 e	0.29556 f	0.39179 de

Level of significance - 1%

5% LSD = 0.0097

Data followed by a common letter are not significantly different.

The heaviest 100 seed weight was obtained at P_1A followed by that at P_3A. Lightest 100 seed weights were obtained with combinations of C with all levels of phosphorus.

2. Root length

The large grade (A) (above 2.00 mm), medium grade (B), between 1.70 and 2.00 mm, small grade (C) below 1.70 mm) and ungraded (D) seeds were germinated and the root length measured after 48, 72 and 96 hours. The treatments had a significant effect on root length. The results are presented in Tables 72 and 73.

a. Root length after 48 hours

Table 72. Phosphorus and seed grade effect on mean root length (cm) after 48 hours.

	A	B	C	D
P_1	0.63 c	0.82 bc	0.74 bc	0.74 bc
P_2	0.67 c	0.78 bc	0.78 bc	0.65 c
P_3	1.03 a	0.86 a	0.86 a	0.77 bc
P_4	0.71 bc	0.52 c	0.88 a	0.75 bc

Level of significance - 1% level

5% LSD = 0.163

Data followed by a common letter are not significantly different.

The treatments P_3A, P_3B, P_3C and P_4C had the longest roots after 48 hours while P_4B, P_2D , P_1A and P_2A had the shortest root.

Table 73. Phosphorus and seed grade main effect on root length after 48 hours

Treatment	Root length (cm)	Level of significance	5% LSD
P_1	0.73 b		
P_2	0.72 b	1%	0.082
P_3	0.88 a		
P_4	0.71 b		
A	0.76 a		
B	0.79 a		
C	0.81 a	N.S.	
D	0.73 a		

Numbers followed by a common letter in each treatment are not significantly different.

It is seen from the table that only P_3 had a significantly longer root length while the remainder of the phosphorus levels had a similar result. Although grade C seeds had produced a longer root length than other grade seeds, the result was not significant.

b. Root length after 72 hours

Table 74. Phosphorus and seed grade effect on mean root length (cm) after 72 hours

	A	B	C	D
P_1	2.32 c	3.04 ab	2.89 ab	2.37 c
P_2	2.50 b	2.92 ab	2.77 b	2.66 b
P_3	3.32 a	2.82 b	2.62 b	2.32 c
P_4	2.72 b	2.36 c	2.65 b	2.69 b

Level of significance - 1% level

5% LSD = 0.431

Data followed by a common letter are not significantly different.

The treatments P_3A followed by P_1B, P_2B and P_1C had longer roots after 72 hours of growth. The shortest roots were obtained at P_1A, P_1D, P_3D and P_4B.

Table 75. Phosphorus and seed grade main effect on root length (cm) after 72 hours

Treatment	Root length (cm)	Level of significance
P_1	2.66	
P_2	2.71	N.S.
P_3	2.77	
P_4	2.60	
A	2.72	
B	2.79	N.S.
C	2.73	
D	2.51	

Phosphorus and seed grades main effect had produced no significant difference in root length after72 hours of growth. The slightly increased root length of the P_3 material did not reach significance level. Similarly grade B seedlings had large roots but this was not significantly different from roots produced by other seed grades.

c. Root length after 96 hours

Table 76. Phosphorus and seed grade effect on mean root length (cm) after 96 hours.

	A	B	C	D
P_1	4.49 c	5.34 ab	4.85 bc	5.00 bc
P_2	5.68 a	4.98 bc	5.00 bc	5.02 bc
P_3	5.29 ab	5.09 b	4.61 bc	4.48 c
P_4	4.81 bc	4.52 c	4.99 bc	4.83 bc

Level of significance - 1% level 5% LSD = 0.53

Data followed by a common letter are not significantly different.

It can be observed from table 76 that P_2A followed by P_1B and P_3A had produced significantly longer roots while treatments P_1A, P_4B and P_3D had shorter roots.

Table 77. Phosphorus and seed grade main effect on root length after 96 hours

Treatments	Root length (cm)	Level of significance	5% LSD
P_1	4.92 ab		
P_2	5.17 a	5%	0.266
P_3	4.84 b		
P_4	4.79 b		
A	5.07 a		
B	4.98 a	N.S.	
C	4.86 a		
D	4.92 a		

P_2 followed by P_1 had produced longer roots after 96 hours of growth. The root length obtained at P_1, P_3 and P_4 was not significantly different. P_2 P_1 P_4 P_3

Treatment level underscored by common line had produced root which were not significantly different.

Seed grade did not show a significant effect on root length, although there is a trend to suggest that root length decreased with decrease in seed grade. (A ← B ← C). Ungraded seed had produced root lengths slightly longer than those produced by grade C seeds.

3. Standard germination

Standard germination of the seeds showed that phosphorus had significant effect on the percentage of germination at the 5% level. The result is shown in Table 78.

Table 78. The effect of phosphorus on germination

Treatment	Germination %	Level of significance	5% LSD
P_1	95.5 a		
P_2	90.75 b	1%	3.87
P_3	90.5 b		
P_4	96.5 a		

The fourth level of phosphorus (P_4) followed by P_1 had shown significantly higher germination percentage than P_2 and P_3. There was no difference between P_2 and P_3.

4. Controlled deterioration

The germination percentages of theseeds after controlled deterioration were transformed into angles and statistically analysed. The result showed that phosphorus had a significant effect on germination at the 5% level. The result is shown in Table 79.

Table 79. The effect of level of phosphorus on germination after controlled deterioration.

Level	Germination	Level of significance	5% LSD
P_1	49.51 b		
P_2	48.49 b		
P_3	57.5 a		
P_4	55.27 a		

The third level of phosphorus (P_3) had the highest germination after controlled deterioration. Germination at P_4 was not significantly different from P_3. Lower levels of phosphorus, P_1 and P_2 had significantly lower germination.

5. Seedling emergence (peat)

There was no significant difference in the emergence of seedling percentage in peat. The result is shown in Table 80.

Table 80. The effect of phosphorus on seedling emergence (%)

Level of phosphorus	% emergence	Level of significance
P_1	89.42	
P_2	89.67	N.S.
P_3	91.42	
P_4	92.00	

With increase in phosphorus level there is a small but not significant increase in percentage of seedling emergence.

6. Normal Seedling

The phosphorus treatments had no significant effect on the production of normal vigorous seedlings. The result is shown in Table 81.

Table 81. The effect of phosphorus on normal seedling

Level of phosphorus	Normal seedling	Level of significance
P_1	78.1	
P_2	77.9	N.S.
P_3	73.0	
P_4	76.1	

The percentage normal seedling after transforming into angles showed that levels of phosphorus had no significant effect on normal seedling. Although P_3 had the lower normal seedling than other treatments, it did not reach a level of significance.

Experiment 5

Effect of nitrogen and phosphorus on mustard broad-leaf seed

1. Seed Yield

Nitrogen had a significant effect on the seed yield of mustard broad leaf at 1% level. P and N P interactions had no significant effect on seed yield. N and P and their interactions effects are shown in Tables 82 and 83.

Table 82. N and P main effect on mean seed yield (g) of mustard broad leaf

Level of nutrients	Seed yield (g)	Level of significance	5% LSD
N_1	10.14 c		
N_2	14.74 b	1%	1.17
N_3	18.47 a		
P_1	14.94 a		
P_2	14.17 a	N.S.	-
P_3	14.24 a		

Numbers followed by common letters for each nutrient are not significantly different.

The results show that there was a significant increase in mean seed yield with increase in levels of nitrogen. Phosphorus on the other hand had produced no differences in mean seed yield. Nitrogen and phosphorus main effects on seed yield are given in Fig. 3.

Table 83. The effect of N P interactions on mean seed yield (g) of mustard broad leaf

	P_1	P_2	P_3
N_1	10.04	10.64	9.75
N_2	15.27	15.07	13.87
N_3	19.51	16.79	19.11

There was no significant interaction effect of N P on mean seed yield. At all levels of phosphorus, the yield increased with increase in nitrogen level. However, the increase in yield at N_3P_2 was not similar to yield increase at N_3P or N_3P_3. But this difference was not significant. N P interaction effect is shown in Fig. 4.

2. Distribution of seed grade

The seeds were divided into two size grades. grade A, above 1.4 mm and grade B below 1.4 mm. The analysis of variance showed that N and P main effect or their interactions had no significant effect on the distribution percentage of a size-grade seeds. The result is presented in Table 84.

Table 84. N and P main effect on grade A seed (percentage)

Level of Nutrients	%	Level of significance
N_1	71.75	
N_2	69.30	N.S.
N_3	76.38	
P_1	73.84	
P_2	71.70	N.S.
P_3	71.85	

There is a slight increase in grade A (above 1.44 mm) seeds with increase in nitrogen level from N_1 (100 kg/ha) to N_3 (300 kg/ha), the result was not statistically significant. The N_2 level (200 kg/ha) had slightly reduced the grade A seed over the N_1 treatment.

Phosphorus also had no significant effect on the percentage distribution of grade A seed.

Table 85. The effect of N P interactions on percentage distribution of grade A seeds.

	P_1	P_2	P_3
N_1	76.23	65.93	73.00
N_2	72 .33	68.03	67.53
N_3	72.97	81.13	75.03

The interactions of N P had no significant effect on the percentage of mustard broad leaf seeds which were above 1.4 mm. Although the table shows that percentage of grade A seeds was lowest at N_1P_2 and highest at N_3P_2, the differences did not reach significance level.

3: 100 Seed Weight

The analysis of variance showed that N, P and their interaction effects on 100 seed weight had a significant effect at the 1% level. The results are shown in Tables 86 and 87.

Table 86. N and P main effect on 100 seed weight (g)

Level of nutrients	100 seed weight (g)	Level of significance	5% LSD
N_1	0.1806 b		
N_2	0.1821 b	1%	0.0021
N_3	0.1868 a		
P_1	0.1859 a		
P_2	0.1829 b	1%	0.0021
P_3	0.1807 c		

Numbers followed by a common letter in each treatment were not significantly different.

There is a general trend which suggests that the increase in nitrogen level produced heavier seeds but the 100 seed weight from the lower level of nitrogen (N_1) and medium level of nitrogen (N_2) were not significantly different. The heaviest seeds were produced by the mother plants receiving the highest level of nitrogen (N_3). $N_3 \leftarrow \underline{N_2 \leftarrow N_1}$

Conversely an increase in the phosphorus level resulted in a significant decrease in 100 seed weight $P_1 < P_2 < P_3$

Table 87. The effect of N P interactions on 100 seed weight (g)

	P_1	P_2	P_3
N_1	0.1854 bc	0.1729 e	0.1834 c
N_2	0.1844 bc	0.1814 cd	0.1805 cd
N_3	0.1879 b	0.1945 a	0.1781 d

Level of significance - 1%

5% LSD = 0.0036

Data followed by a common letter are not significantly different.

It can be observed from the table that N_3P_2 has resulted in the heaviest 100 seed weight while N_1P_2 resulted in the lightest 100 seed weight. The interaction of P_1 with all levels of nitrogen generally had heavier seeds than interactions of P_3 with nitrogen levels. Interactions of P_2 with different levels of nitrogen showed that while higher level of nitrogen had the heaviest 100 seed weight, the lower level of nitrogen produced the lighest seeds.

4. Standard germination

The analysis of variance showed that N, P and their interactions had significant effect on mean germination percentage of mustard broad leaf seeds. The results are presented in Tables 88 and 89.

Table 88. N and P main effects on mean germination percentage

Level of nutrients	Germination %	Level of significance	5% LSD
N_1	99.17 a		
N_2	95.92 b	1%	1.27
N_3	98.75 a		
P_1	99.17 a		
P_2	96.17 b	1%	1.27
P_3	98.50 a		

Data followed by a common letter are not significantly different.

The medium level of nitrogen (N_2) resulted in significantly lower germination percentage than higher (N_3) or lower (N_1) levels of nitrogen. Similarly medium levels of phosphorus also resulted in lower mean germination percentage.

Table 89. The effect of N P interactions on mean germination percentage

	P_1	P_2	P_3
N_1	100.00 a	98.00 ab	99.50 ab
N_2	98.00 ab	91.50 c	98.25 ab
N_3	99.50 ab	99.00 ab	97.75 b

Level of significance - 1%

5% LSD = 2.20

The treatment combination N_1P_1 resulted in the highest mean germination percentage. N_2P_2 had the lowest mean germination percentage.

5. Seedling emergence (peat)

The percentage emergence of seedling were transformed into angles before statistical analysis. The seed grade, nitrogen and N P interactions were significant at the 1% level. Other treatment effects were not significant. The data is presented in Tables 90, 91, 92, 93 and 94.

Table 90. Seedling emergence in relation to N P and seed grade effects

		A	B
	P_1	78.18 a	67.79 ab
N_1	P_2	70.62 ab	54.53 bc
	P_3	60.97 b	61.48 b
	P_1	58.65 bc	54.82 bc
N_2	P_2	55.38 bc	38.80 d
	P_3	59.66 bc	49.23 bc
	P_1	47.04 bc	45.41 c
N_3	P_2	60.01 b	55.68 bc
	P_3	63.66 ab	64.61 ab

Level of significance - 1% level

5% LSD = 14.61

Data followed by a common letter are not significantly different.

The treatment N_1P_1A had the highest seedling emergence and N_2P_2B had the lowest.

Table 91. N, P and seed grade main effects on seedling emergence

Level of treatment	Seedling emergence	level of significance	5% LSD
N_1	65.6 a		
N_2	52.8 b	1%	5.97
N_3	56.1 b		
P_1	58.6 a		
P_2	55.8 a	N.S.	
P_3	59.9 a		
A	61.6 a	1%	4.87
B	54.7 b		

Numbers followed by a common letter in each treatment are not significantly different.

There was better seedling emergence at the lower level of nitrogen (N_1) than the medium or higher levels. The difference in emergence at N_3 and N_2 was not significant. Phosphorus failed to show significant differences in seedling emergence while grade A seeds had significantly superior emergence over grade B seeds.

Table 92. The effect of N P interactions on seedling emergence

	P_1	P_2	P_3
N_1	72.98 a	62.57 b	61.23 b
N_2	56.73 bc	47.09 c	54.45 bc
N_3	46.22 c	57.85 b	64.13 ab

Level of significance - 1% level

5% LSD = 10.33

Data followed by a common letter are not significantly different.

The combination N_1P_1 produced the highest seedling emergence followed by N_3P_3. The lowest seedling emergence was produced by N_3P_1 and N_2P_2.

Table 93. The effect of nitrogen and seed grade interactions on seedling emergence

	A	B
N_1	69.9	61.3
N_2	57.9	47.6
N_3	56.9	55.2

Level of significance - N.S.

The interactions effect of nitrogen levels and seed grade was not significant. The best seedling emergence was from N_1 followed by N_3 and then N_2. This trend was similar with both seed grades.

Table 94. The effect of phosphorus and seed grade interactions on seedling emergence

	A	B
P_1	61.3	56.0
P_2	62.0	49.7
P_3	61.4	58.4

Level of significance - not significant.

The analysis of variance showed that the interaction effect of phosphorus and seed grade were not significant. Only treatment combination P_2B produced low emergence but the difference did not reach significance level.

6. Mean time of emergence

The phosphorus and seed grade main effect and the interaction effect of NP, NG (nitrogen and grade), PG, and NPG had no significant effect on mean time of seedling emergence. Only the nitrogen effect was significant at the 5% level. The results arepresented in Tables 95 and 96.

Table 95. N P and seed grade effects on mean time of emergence (days)

		A	B
	P_1	5.627	5.652
N_1	P_2	5.233	5.508
	P_3	5.641	5.747
	P_1	5.475	5.733
N_2	P_2	5.828	5.835
	P_3	5.855	5.892
	P_1	5.856	5.825
N_3	P_2	5.618	6.089
	P_3	5.1725	5.848

Level of significance - not significant.

It is evident from the data that the differences between treatments in mean days to seedling emergence was small and not significant.

Table 96. N, P and seed grade main effect on mean time to seedling emergence (days)

Nutrient level	Meant time (days)	Level of significance	5% LSD
N_1	5.568 a		
N_2	5.770 b	5%	0.191
N_3	5.827 b		
P_1	5.695 a		
P_2	5.685 a	N.S.	
P_3	5.785 a		
A	5.651 a	N.S.	
B	5.792 a		

Numbers followed by a common letter in each treatment are not significantly different.

Only the lower level of nitrogen (N_1) had mean days to emergence which was significantly less than N_2 or N_3. Phosphorus levels and seed grade also failed to reach significance level.

7. Normal seedlings

The percentage of normal seedlings produced by seeds at the combination of three levels of nitrogen, three levels of phosphorus and two size grades (A, above 1.4 mm seeds and below 1.4 mm seeds) were transformed into angles and the analysis of variance showed that nitrogen, and size grades of seeds had a significant effect on the production of normal seedlings. The result is presented in Tables 97, 98 and 99.

Table 97. N, P and seed grade main effect on production of normal seedlings.

Treatment	Normal seedlings	Level of significance	5% LSD
N_1	77.43 a		
N_2	60.34 c	1%	5.72
N_3	66.79 b		
P_1	69.56 a		
P_2	65.51 a	N.S.	
P_3	69.69 a		
A	74.77 a	1%	4.67
B	61.74 b		

Numbers followed by a common letter in each treatment are not significantly different.

Seeds produced at the lowest level of nitrogen (N_1) had significantly higher normal seedling percentages. Seeds produced at N_3 had medium normal seedlings while seeds produced at medium level of nitrogen (N_2) resulted in lowest percentage of normal seedlings. Regarding the effect of phosphorus, the seeds produced at different phosphorus levels did not show a significant difference although the medium level of phosphorus (P_2) had a slightly lower percentage of normal seedlings. Grade A seeds had a significantly larger number of normal seedlings than grade B seeds.

Table 98. The N P interaction effect on normal seedlings.

	P_1	P_2	P_3
N_1	87.48 a	75.0 b	69.82 bc
N_2	69.45 bc	50.35 d	61.82 c
N_3	51.75 d	71.19 bc	77.44 b

Level of significance - 1%

5% LSD = 9.9

Data followed by a common letter are not significantly different.

The combination N_1P_1 had the highest normal seedlings, while treatment combinations N_2P_2 and N_3P_1 had the lowest normal seedlings.

Table 99. N, P and seed grade interaction effects on normal seedlings.

		A	B
	P_1	91.63 a	83.33 ab
N_1	P_2	89.60 ab	60.40 c
	P_3	72.23 bc	67.40 bc
	P_1	74.30 bc	64.60 bc
N_2	P_2	65.97 bc	34.73 d
	P_3	72.23 bc	51.54 c
	P_1	53.5 c	50.00 c
N_3	P_2	74.3 bc	68.07 bc
	P_3	79.17 ab	75.70 b

Table 99 continued

Level of significance - 1% level

5% LSD = 14.0

Data followed by a common letter are not significantly different.

The table shows the wide range of numbers of normal seedlings as a result of N P and grade. N_1P_1A resultes in the largest percentage of normal seedlings, while N_2P_2B had the lowest.

8. Mean seedling dry weight

The result showed that only seed grade had a significant effect on mean seedling dry weight. Nitrogen, phosphorus, or the interactions of N P, nitrogen grade (NG), phosphorus grade (PG) had no significant effect on mean seedling dry weight.

Table 100 Mean seedling dry weight in relation to nitrogen, phosphorus and seed grade interactions

		A	B
	P_1	0.0271 a	0.0226 b
N_1	P_2	0.0294 a	0.0213 bc
	P_3	0.0234 b	0.0218 bc
	P_1	0.0281 ab	0.0192 bc
N_2	P_2	0.0270 ab	0.0170 c
	P_3	0.0253 ab	0.0200 bc
	P_1	0.0248 ab	0.0200 bc
N_3	P_2	0.255 ab	0.0207 bc
	P_3	0.0262 ab	0.0202 bc

Table 100 (continued)

Level of significance - 1%

5% LSD = 0.0049

Data followed by a common letter are not significantly different.

It can be seen from the data that the mean seedling dry weight is generally higher at all combinations of A with N and P. Grade B seeds with combination with all N and P had generally lower mean seedling dry weight. The highest mean seedling dry weight was produced at N_1P_1A, N_1P_2A and the lowest at N_2P_2B.

Table 101. N, P and seed grade main effect on mean seedling dry weight (g)

Nutrients	Mean Dry Weight (g)	Level of significance	5% LSD
N_1	0.0243 a		
N_2	0.0228 a	N.S.	
N_3	0.0229 a		
P_1	0.0236 a		
P_2	0.0235 a	N.S.	
P_3	0.0228 a		
A	0.0263 a	1%	0.0028
B	0.0203 b		

Numbers followed by a common letter in each treatment are not significantly different.

It is seen from the table that the nitrogen and phosphorus main effect had produced no significant effect. Only grade A seeds had significantly higher mean seedling dry weights.

DISCUSSION

DISCUSSION

Seed Yield

The seed yield of cauliflower was studied in experiments 2, 3 and 4. In experiment 2, which was conducted in the glasshouse, increases in the levels of N, P, K or their interactions did not produce a significant increase in the seed yield of cauliflower (Tables 2, 3, 4, 5, 6 and Fig. 1).

In experiment 3, where the nitrogen was applied in three split applications in the field, the increase in nitrogen levels from N_1 (50 kg/ha) to N_2 (150 kg/ha), N_3 (250 kg/ha) and N_4 (350 kg/ha) resulted in a non-significant increase in the seed yield of 4.5%, 16.8% and 8.4% respectively (Table 53 and Fig. 2.). There is a consistent increase in the seed yield up to N_3, the further application of nitrogen to N_4 resulted in a small decrease (2.5%) over N_3.

In the fourth experiment, the application of phosphorus did not produce significant differences in the seed yield (Table 68). There is no trend in the effect of increased levels of phosphorus and all levels of phosphorus produced similar results.

According to Aamlid (1952), the cauliflower curd consists of repeatedly branched terminal portion of main axis of the plant. The number of apices on the curd may be up to 5 millions if the primary, secondary and tertiary and other branches are included. Only a relatively small number of apices develop into flowers. Others are suppressed. The suppressed apices may remain alive and some of them may develop into flowers at a later time or there may be secondary infection by micro-organisms and the suppressed apices may become infected with pathogens and start to rot.

An increase in applied nitrogen increases the curd size but because not all apices develop into flowers, the large part of the curd may be suppressed by elongating flower stalks and they may subsequently rot. Novak (1974) stated that higher doses of nitrogen up to 180 kg/ha applied before planting and early stage of growth resulted in high quality large size curd but such curds were more susceptible to secondary infection and thus seed yield was reduced. He found 24.3% lower seed yield when the nitrogen level was increased to 142 - 152 kg/ha from 60 - 90 kg/ha. However, when nitrogen was applied in split doses, addition of nitrogen in two split doses of up to 112 kg/ha (Shah and Hussain, 1978) and in poor soils, four split doses of up to 500 kg/ha (Gill *et al.*, 1975) have increased the seed yield.

In the second experiment in the glasshouse, where all nitrogen was applied as a base dressing, the increased levels of nitrogen resulted in more luxuriant growth and a large curd. The relatively high humidity in the glasshouse probably contributed to the rotting of parts of the curd which had not developed into flower stalks. It is possible that this affected the result in that nitrogen did not produce an increase in seed yield. In the third experiment which was conducted in the field, the total nitrogen levels of up to 250 kg/ha but applied in three split doses did not decrease but gave a steady although non-significant increase in the seed yield. This may be attributed to better utilization of nitrogen for higher yield. However, levels higher than 250 kg/ha, even applied in three split doses resulted in increased incidence of curd rotting and hence the seed yield started decreasing.

Eguchi (1960) applied nitrogen fertilizer to cabbage and chinese cabbage plants as base dressing and side dressed at various stages of growth of plant. He found that plants receiving nitrogen as a side dressing along with base dressings produced a higher seed yield than those receiving nitrogen only as a base dressing. It would seem that nitrogenous fertilizer side dressed near the bolting time influenced the development of secondary branches and flower buds and thus resulted in increased seed yield than all nitrogen applied as base dressing.

Holmes (1980) reported that the application of phosphatic and potassic fertilizers do not often influence the yield of rape-seed or other brassica crops. Where phosphorus and potassium do increase the seed yield, it is normally on a soil of low or very low phosphorus and potassium levels. Shah and Hussain (1978) reported no significant increase in seed yield of cauliflower from an increase in the levels of phosphorus and potassium. But Gill *et al.* (1975) found that when the phosphorus level in the soil was comparatively low there was an increase in the seed yield of cauliflower due to the application of phosphorus up to 100 kg/ha. The soil analysis of the present experimental sites had indicated that phosphorus and potassium indices were 3 and 2 respectively. The initial content of phosphorus and potassium which was comparatively high compared with Gill *et al.* (1975) could have been the reason why the addition of these nutrients did not significantly increase seed yield of cauliflower.

The effect of nitrogen and phosphorus on the seed yield of mustard broad leaf (experiment 5) shows that increase in the levels of nitrogen applied to the soil significantly increased the seed yield but P and NP interactions had no significant effect (Tables 82, 83 and Fig. 3,4). Tbere was an increase of 45.4% and 82.1% at N_2 (200 kg/ha) and N_3 (300 kg/ha) respectively over N_1 (100 kg/ha). The effect of nitorgen on seed yield of Indian mustard, rape and turnip have been reported by several workers including Bhan *et al.*, Sen *et al.* (1975), and Holmes, (1980). They reported that increase in nitrogen increased the number of branches, siliqua per plant, siliqua length and/or seed per siliqua. In Indian conditions, levels of nitrogen higher than 60 kg/ha were not found economical (Sen *et al.*, 1975) and in British conditions, levels of nitrogen above 200 kg/ha depressed the seed yield of winter and summer rape (Scott *et al.*, 1973). In the present experiment, the levels of nitrogen were above those used by these workers who studied the effect under field conditions but the present work was conducted in containers with field soil. Bunt (1976) has reported that leaching is responsible for up to 87% loss of nitrogen from a mixture of peat and sand (3:1). Loss of some of nitrogen through leaching and application of nitrogen in 3 split applications, may be the reason why there was seed yield increase even up to the level of 300 kg/ha. It is probable that a split application of nitrogen assisted the improved utilization by the plants. There was an increased vegetative growth and number of siliqua as a result of increased nitrogen levels.

Phosphorus has generally not been regarded as influencing the seed yield of mustard if it is not lacking from the root zone (Homes, 1980). The initial phosphorus content in the soil was high (phosphorus index 6) therefore the availability of additional phosphorus had no effect on seed yield. Similar results have been reported by Jain and Jain (1979) and Pandey *et al.* (1979) working with mustard and Holmes (1980) with rape.

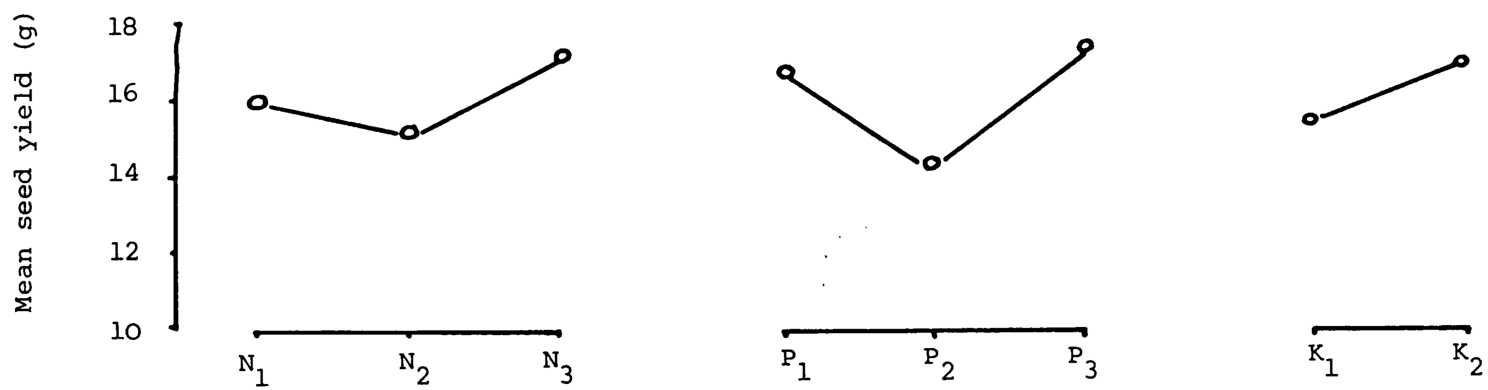

Fig. 1. N, P and K main effect on seed yield of cauliflower.

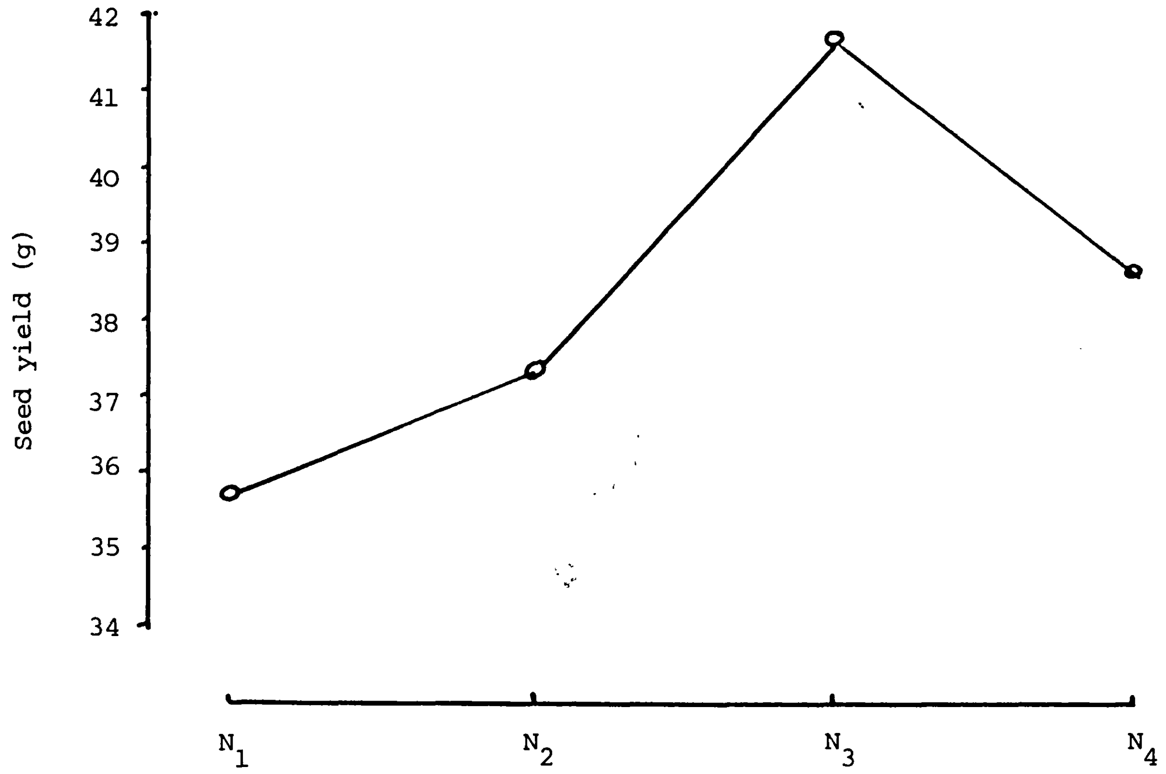

Fig. 2. Effect of nitrogen on seed yield of cauliflower

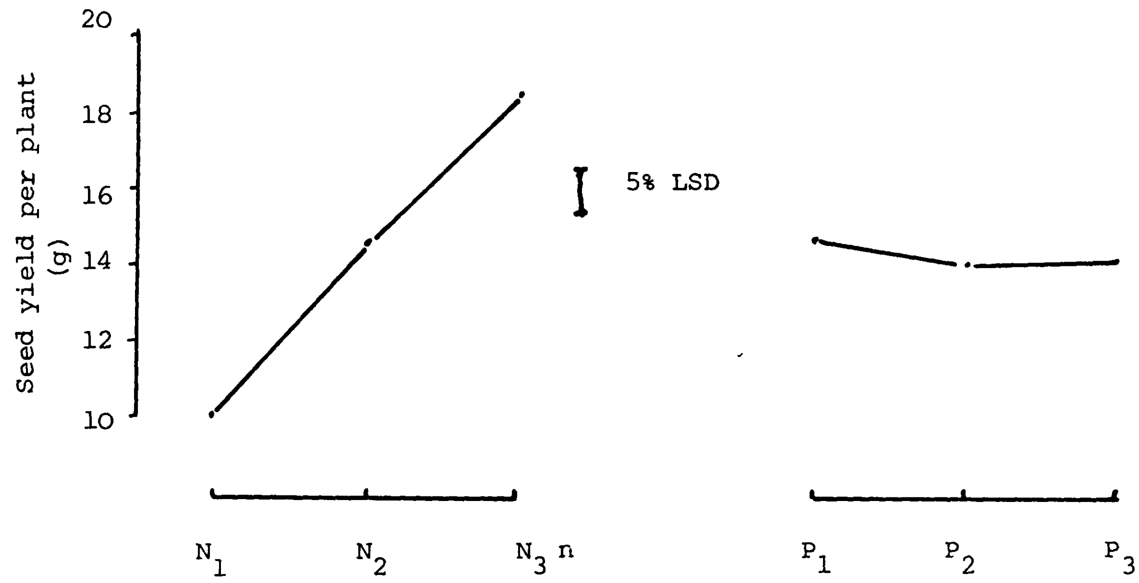

Fig. 3. Nitrogen and phosphorus main effect on seed yield of mustard broad leaf.

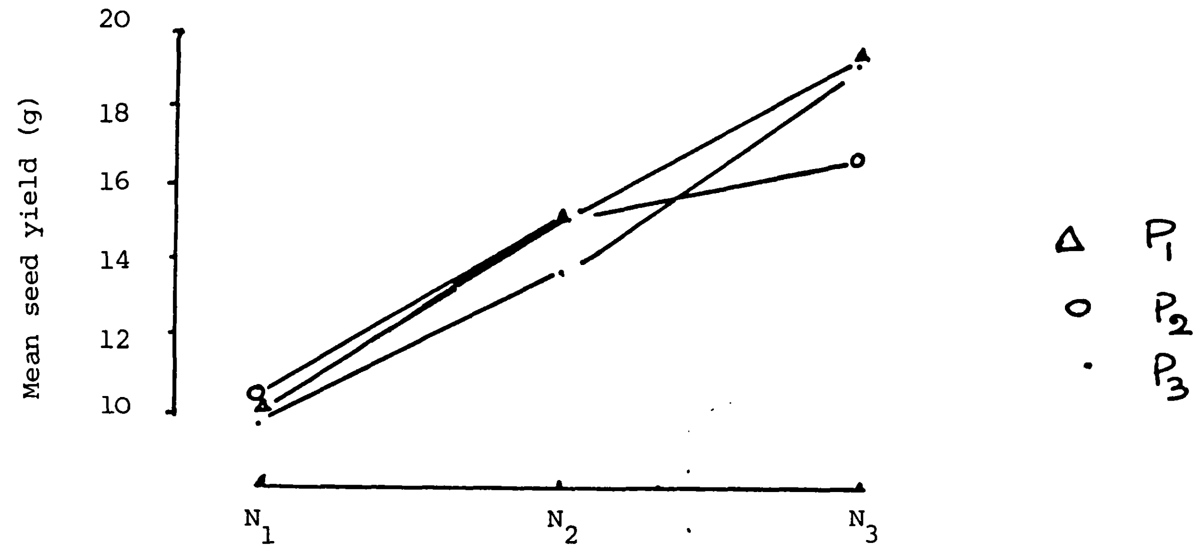

Fig. 4. Effect of N and P interaction on seed yield of mustard broad leaf

Standard Germination

Seeds obtained from all the experiments were tested for standard germination as described by ISTA (1966).

In the second experiment N, P, K and their interactions had a small but significant effect on seed germination of cauliflower. The addition of phosphorus increased the percentage germination but an increase in potassium (Table 13, Fig. 5) decreased it. NP and NK interactions had also significantly affected germination percentage. There was an increase in germination from P_1 to P_2 at all nitrogen levels but while it continued to increase at P_3 with medium level of nitrogen, there was a decrease in germination with higher and lower levels of nitrogen (Fig. 6, Table 14). Increase in potassium level at P_1 and P_3 decreased the germination but did not decrease at P_2. (Fig. 7, Table 16). In the third experiment, an increase in nitrogen from N_1 to N_2, N_3 and N_4 produced small and non-significant increase of 4.2%, 3.2% and 2.4% germination (Table 57). But these are too small to be of any practical significance in influencing the seed vigour. In the fourth experiment, the cauliflower seeds produced by first and fourth levels of phosphorus had similar germination but decreased at P_2 and P_3 (Table 78).

With mustard broad leaf seeds (experiment 5), the second levels of both nitrogen and phosphorus and their interactions (N_2P_2) significantly lowered the germination percentage but higher levels of N P and their interactions had similar germination as the first levels of them (Table 88 , 89).

It appears from this result that nitrogen does not play an important role in influencing the germination of cauliflower and mustard seed. Except the medium levels of nitrogen at second and fifth experiments, the results generally showed that the effect of nitrogen on seed germination was small and of no practical significance. This result is generally confirmed by Ahmed (1982) working with Onion and Osman (1982) with sweet pepper (*Capsicum annum* L.)where they did not find an effect of nitrogen on seed germination. Eguchi (1960) also reported no great differences in germination percentage of cabbage and Chinese cabbage seeds.

However, an application of phosphorus has generally produced cauliflower seeds with increased germination percentage and potassium application reduced it. This result is contrary to the result reported by Gavras (1981) and Liaw (1982) with french bean where they reported a decrease in germination percentage due to phosphorus application. In french bean, an increase in the level of phosphorus decreased seed vigour but in cauliflower, it improved it as seen by increased germination and field emergence. However, Iwata and Eguchi (1958) also did not find effects of phosphorus and potassium in Chinese cabbage seed germination. It is possible that only a small amount of potassium is needed for optimum germination and further increases in potassium application depress the germination.

It appears from this result that while increase in nitrogen level does not depress seed germination of cauliflowers and mustard broad leaf, potassium depresses it and phosphorus improves it. But in mustard broad leaf, when higher levels of phosphorus are present in the soil, further increase does not improve germination percentage.

Seed Size

The cauliflower seeds produced in experiments 2 ,3 and 4 were graded into large (A, above 200 mm), medium (B, between 1.7 and 2.0 mm), small (C, below 1.7 mm). In the second experiment, nitrogen, phosphorus or potassium had no effect on percentage distribution of different size seeds (Table 7, Fig. 8). In the third experiment, the fourthe level of nitrogen (N_4) followed by N_2 produced a higher percentage grade A seeds but seeds of other grades were not significantly affected by nitrogen application (Table 54). The third level of phosphorus (P_3) in the third experiment also produced a higher percentage of grade A seeds but grades B and C seeds were not affected by phosphorus application (Table 69). In mustard broad leaf the applications of nitrogen or phosphorus failed to influence the percentage distribution of graded seeds (Table 84). It is clear from the result that except in experiments 3 and 4 where higher levels of nitrogen (N_4) and phosphorus (P_3) respectively produced higher

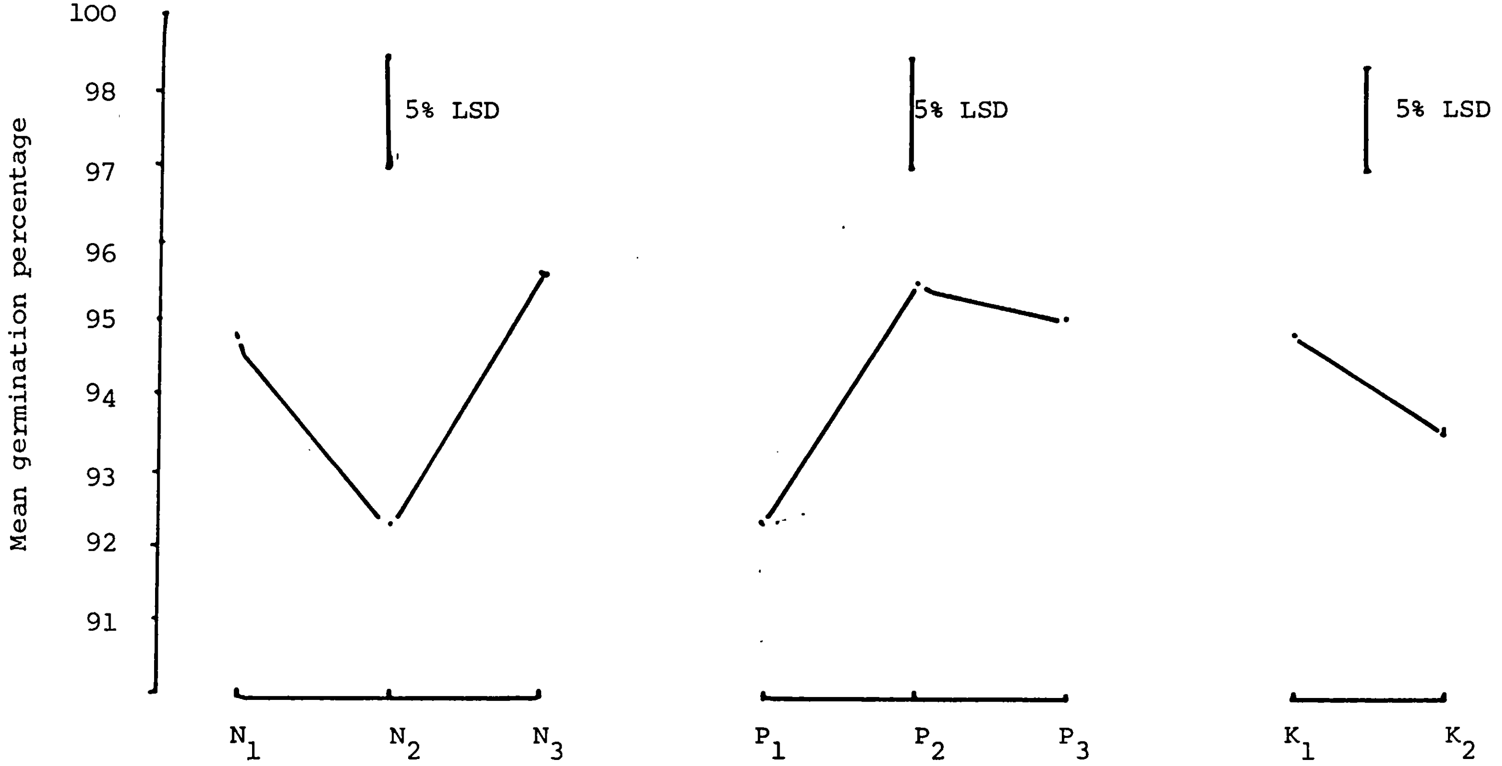

Fig. 5. N, P and K main effects on mean germination percentage of cauliflower seed

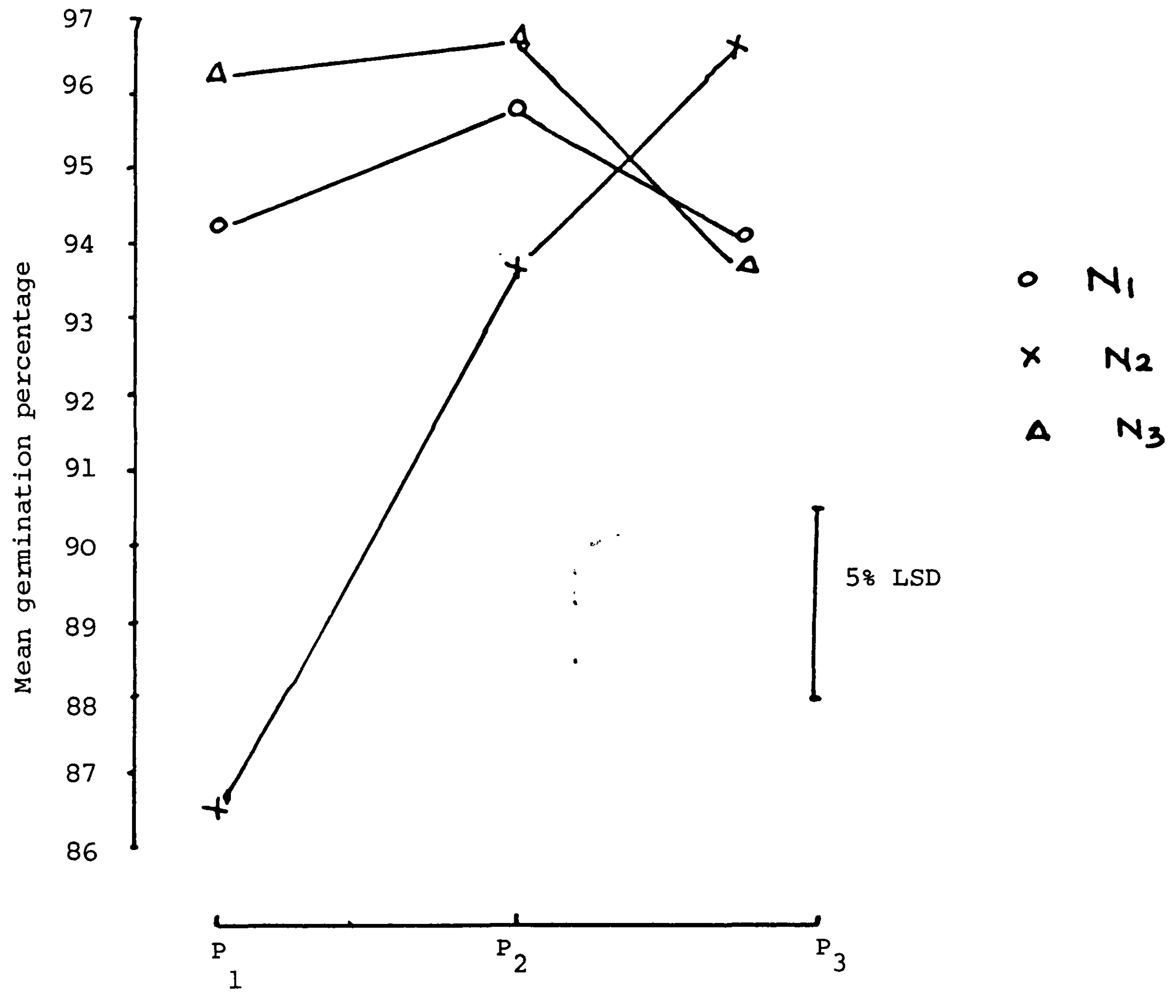

Fig. 6. Effect of N P interactions on mean germination percentage of cauliflower seed

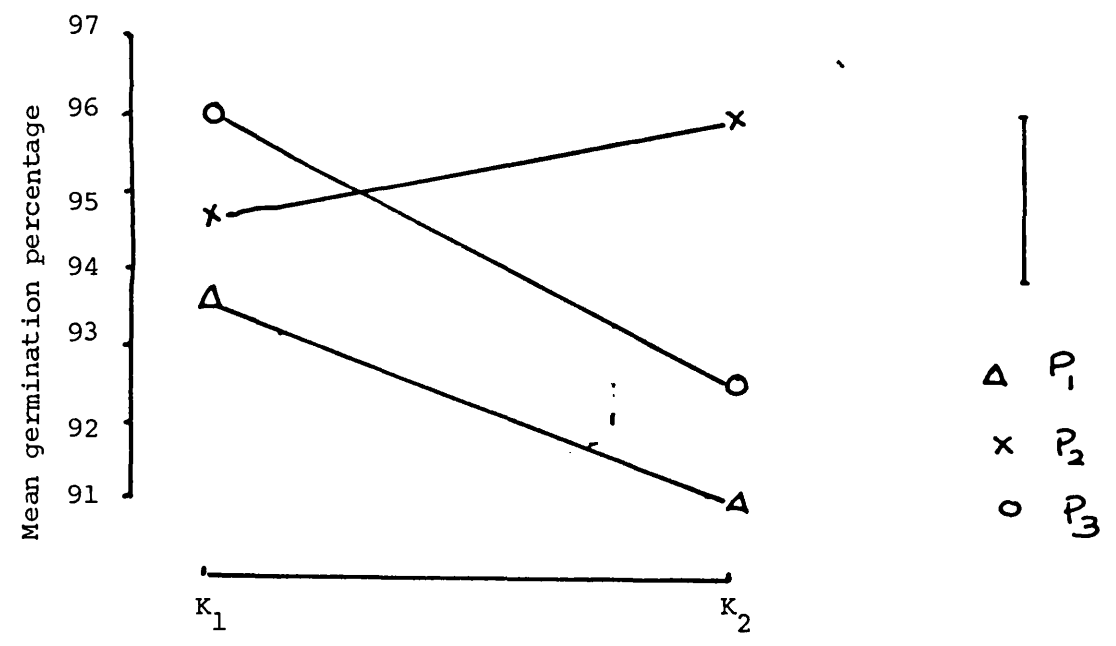

Fig. 7. Effect of P K interactions on mean germination percentage of cauliflower seed

percentage of grade A seeds, the general trend showed that application of nutrients did not affect the grade. This work is confirmed by the work of Austin and Longden (1965) where they reported that mineral nutrition had no effect on seed size distribution in carrot. The effect of position of seed on plant may have an effect on distribution of graded seed. The seeds which mature later in the season may not fully develop and may thus influence seed size. When some plants receive higher rates of a nutrient but not necessarily accompanied by higher seed yield, those seeds produced at an early stage of plant growth may be influenced by the plant nutrition. Better utilization of nutrients by seeds especially in experiments 3 and 4 may have been responsible for the higher percentage of grade A seeds. By increasing the level of nitrogen Singh and Cheema (1972) were able to increase the grade A seeds in radish.

When the seed size was expressed as 100 seed weight, it was found that the material from the second experiment, N, P, K main effects and their interactions effect had a significant influence on seed weight. N_1 produced the heaviest seed while N_2 produced the lightest (Table 8, Fig. 9).

In the case of P effect, increasing the P supply to third level (P_3) significantly increased 100 seed weight compared to P_1 and P_2. But increasing potassium level decreased the seed weight, NP, NK, PK and NPK interactions also affected the seed weight (Tables 9, 10, 11 and 12).

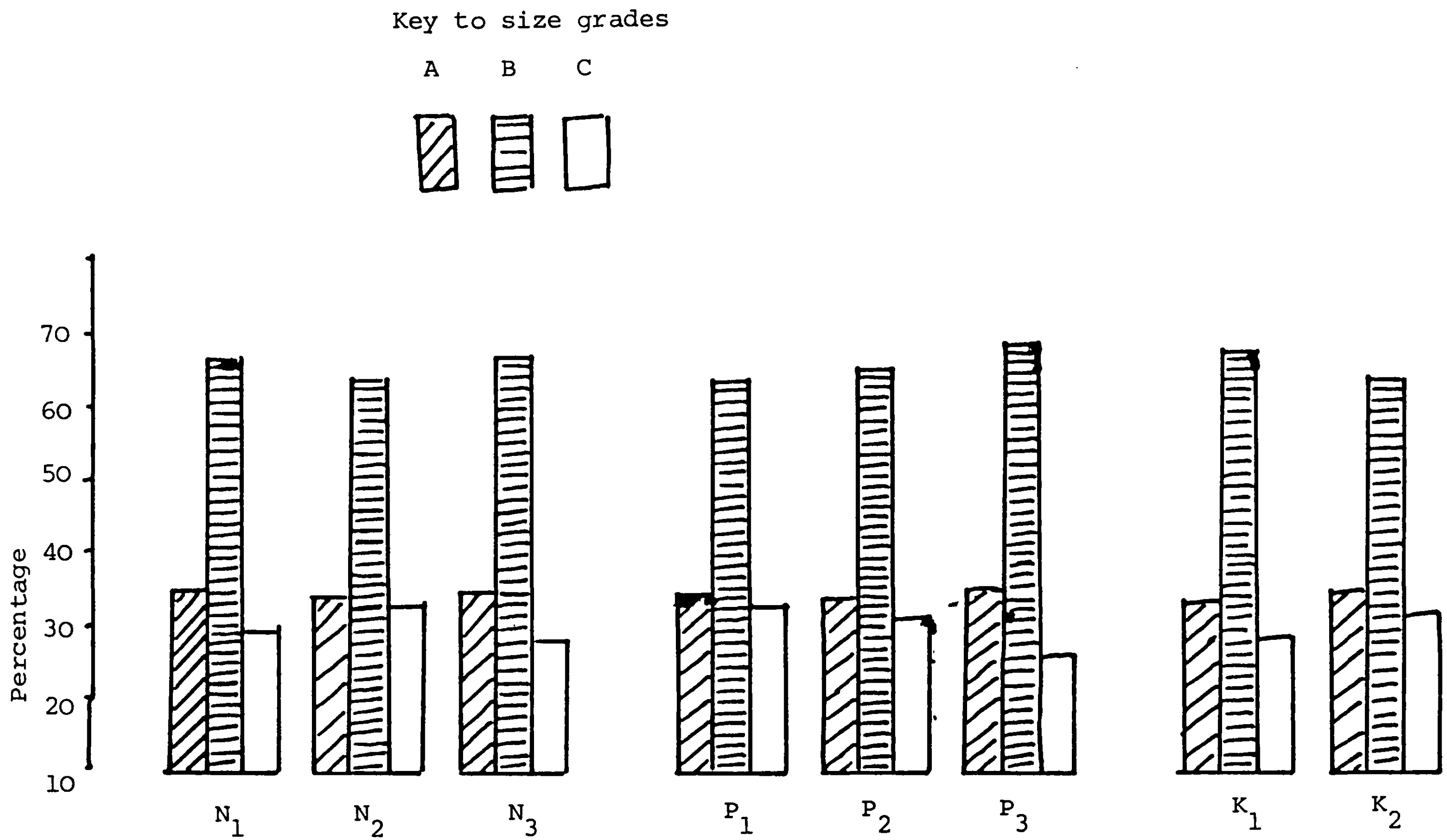

Fig. 8. Effect of N, P and K on percentage of size grades of cauliflower seeds.

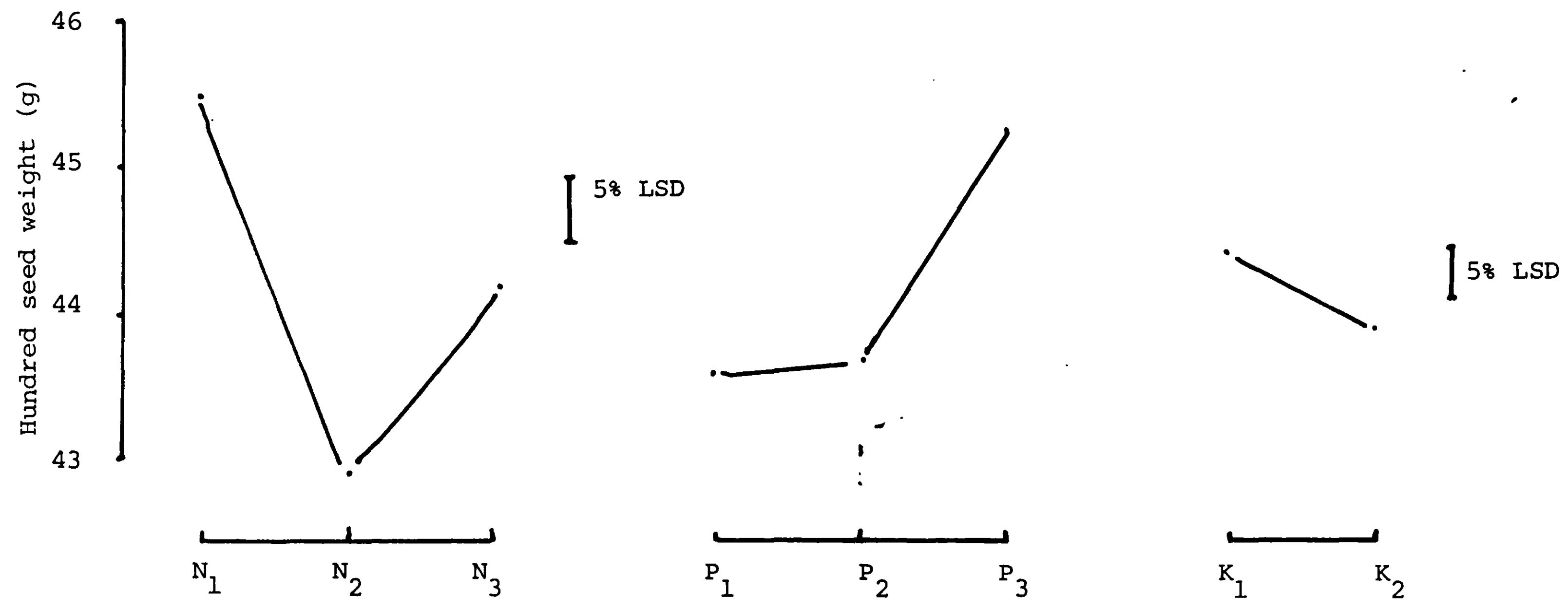

Fig. 9. The N P and K main effects on hundred seed weight of cauliflower.

In the third experiment, N_2 increased the seed weight but further increase in the nitrogen level decreased the 100 seed weight. In the fourth experiment cauliflower seeds produced at P_1 and P_3 were significantly heavier than those produced at P_2 and P_4. In mustard broad leaf plants receiving N_3 produced heavier seeds than those receiving N_1 or N_2. Increases in phosphorus levels decreased the seed weight (Table 86).

Seed size is an important factor especially with modern methods of precision drilling. In addition, heavier or larger seeds have performed better than lighter or smaller seeds. Within a seed lot using only a large seed usually results in increased emergence percentage and earlier emergence. Because of their greater embryo size, reserve and early photosynthesis, large seeds produce larger seedlings and the advantage can persist to increased final yield, particularly for short growing season crops or where economic yield is a storage organ or the seed. Increase in yield are most likely to be obtained where specific yield components are determined during early growth. But the early advantage may not remain in those crops whose plant competition for light, nutrition and water starts earlier and thus earlier advantage is lost. In such crops which are transplanted as in brassicas, the transplanting affects the root system and thus any advantage of larger seeds in plant growth is nullified. But in direct drilled crops, the effect of large seeds is noticed early in the growth before the plants are affected by competition for nutrition, light and water.

It is concluded from the second experiment that a low level of nitrogen and potassium with higher levels of phosphorus produced heavier seeds. The result of the third experiment is also broadly in agreement with the second experiment in that addition of nitrogen did not increase the seed weight. Ahmed (1982) reported no increase in seed weight of onion due to increase in nitrogen level but he found an increase in 100 seed weight at higher levels of phosphorus. Further application of potassium did not increase seed weight when there was sufficient potassium in the soil. However, the effect of higher doses of nitrogen on seed weight of mustard broad leaf did not follow the similar trend as those in cauliflower or onion. Higher levels of nitrogen were responsible for producing heavy seeds.
The effect of plant nutrition on seed size of cauliflower and mustard broad leaf in the present study is in broad agreement with conclusions of Holmes (1980) who reviewed the work of researchers in different countries. He concluded that while nitrogen may increase, decrease or have no effect on seed size of mustard, rape and other brassicas, phosphorus very slightly increased but potassium decreased the seed size.

Root Length

The measurement of root length provided a good indication of seed vigour in lettuce (Smith *et al.*, 1973). The slant test is basically a seedling exhaustion test which measures the growth of root in darkness.

The root length was measured after 72 hours of imbibition of the seeds from the second experiment and after 48, 72 and 96 hours of imbibition of seeds from third and fourth experiments. The slant test for mustard broad leaf seeds was tried but could not be done as these seeds need light for germination and their germination was very irregular in the dark. Exposing the seeds to light may initiate photosynthetic activities which would affect the root growth.

In the seeds from the second experiment, nitrogen had a significant effect in influencing the root length (Table 17, Fig. 10). There was 9.9% and 14.9% increase in the root length with increase in nitrogen levels from N_1 to N_2 and N_3 respectively. The difference in measurement of roots between N_2 and N_3 was not large. The increase in phosphorus levels had produced small but insignificant increase in root length. But potassium increased root length by 5.5% when the level was increased to K_2. The interactions of NP, PK or NK did not affect root length. When all the three nutrients were considered, the highest level of nitrogen and potassium with medium level of phosphorus ($N_3P_2K_2$) produced the longest root and the lowest levels of N P K had produced the shortest root (Table 21).

In the seeds from the third experiment, the second level of nitrogen (N_2) had a significantly longer root after 48 hours,the differences in root produced at different nitrogen levels except N_1 was non-significant after 48 and

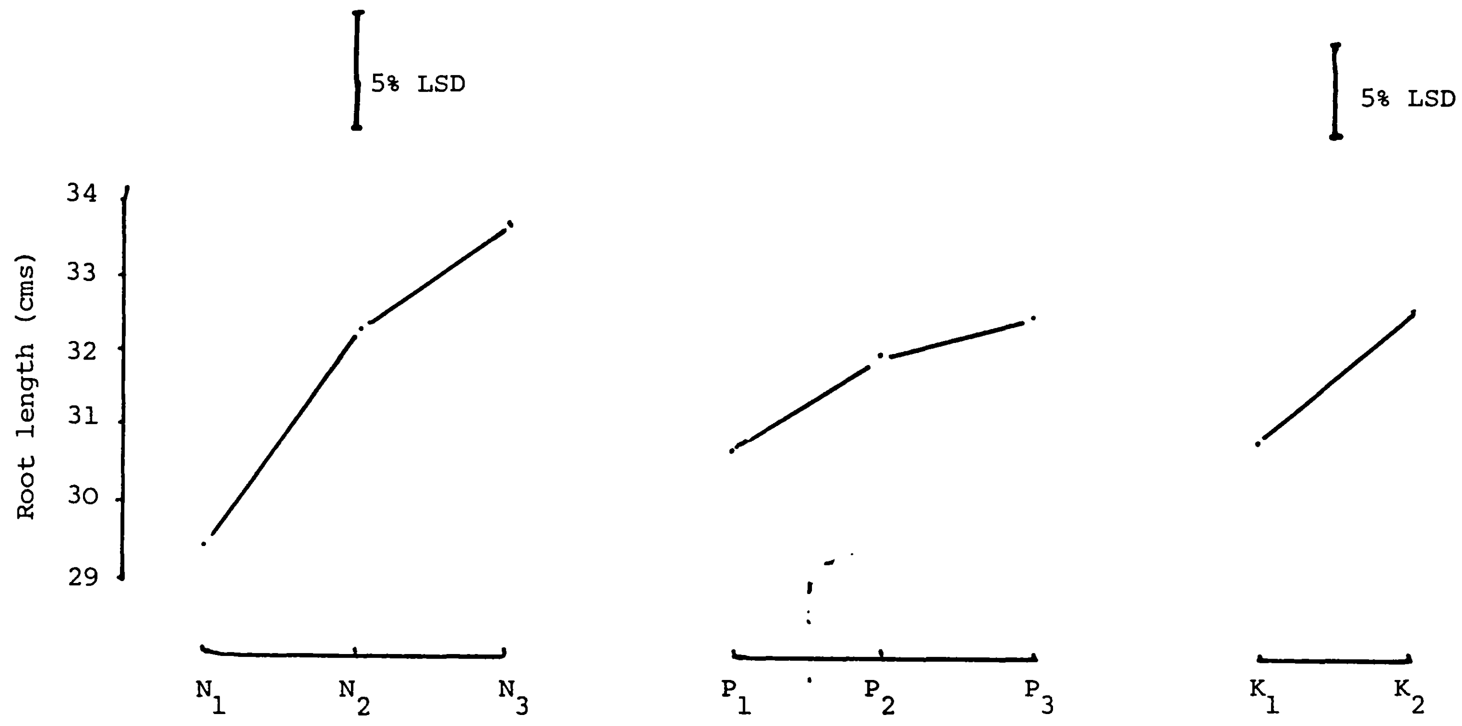

Fig. 10. The effect of different levels of N, P and K on mean root length of cauliflower seeds after 72 hours.

72 hours and the differences between any treatments was not observed after 96 hours (Tables 58, 61, 62 and Fig. 11).

The effect of phosphorus on root length measured showed that third level of phosphorus (P_3) had longer root than others after 48 hours but the difference was not observed after 72 hours. However, after 96 hours, P_1 and P_2 had increased the growth of root over P_3 and P_4 (Tables 73,75 77).

While the second experiment showed the consistent increase in root length with increase in nitrogen level, the third experiment showed no such increase after second level of nitrogen (N_2).

The differences were noticed up to 72 hours after imbibition, the roots produced at all levels of nitrogen was similar after 96 hours. But with phosphorus, the effect was less consistent. While in the second experiment, the phosphorus levels had no significant effect, the initial advantage of root length at P_3 in the fourth experiment stopped after 72 hours. The roots at first and second levels of phosphorus continued to grow faster than P_3 and P_4.

The effect of mother plant nutrition on seedling root growth has not been studied. However work of Atwood (1980) supports the finding of second and third experiments. He

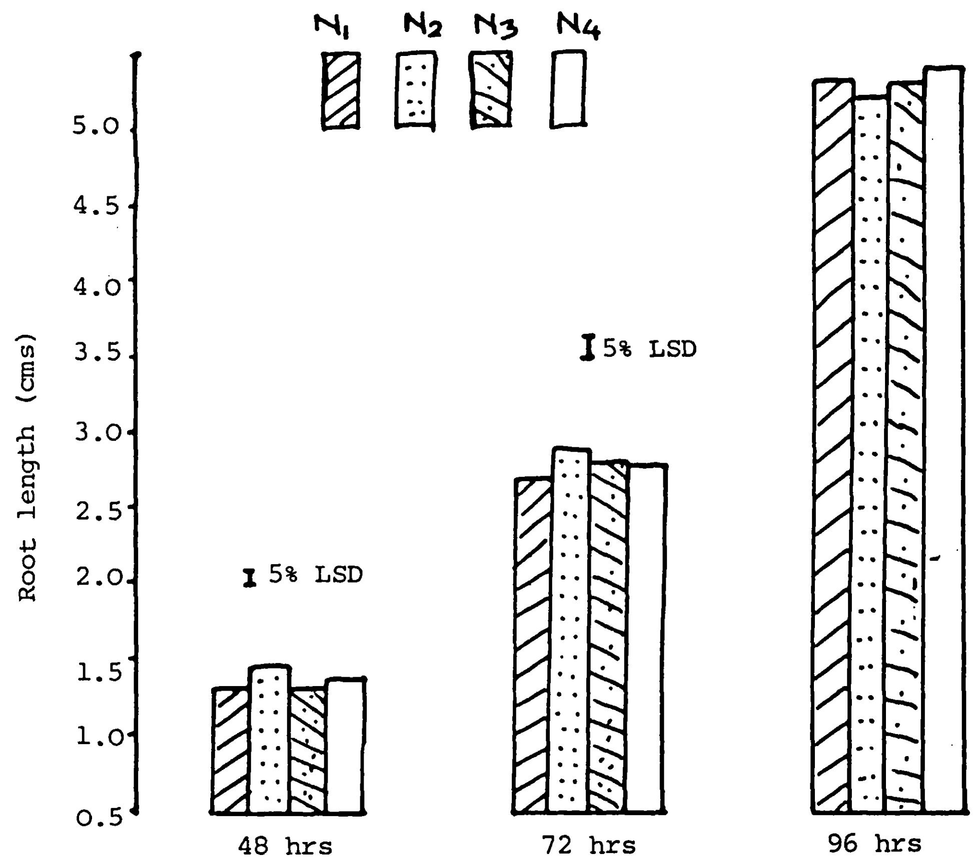

Fig. 11. Effect of nitrogen on root length measured after 48, 72 and 96 hours.

found that high vigour seed of cabbage had significantly longer root in the earlier part of growth (up to 72 hours after imbibition), the differences between different lots were progressively reduced when the root was measured after 96 hours. He suggested that the rate of germination may be more important in vigour determination than actual growth rate of roots. However, Smith *et al*. (1973) found that root length measured after 72 hours had a very high correlation with vigour of lettuce seed. As root growth plays an important role in establishing the plant, it is possible that seeds which show consistently superior root growth will exhibit better performance in direct sown crops. The longer roots will be more helpful in the absorption of nutrients than the smaller roots. However, when such plants are transplanted, the initial advantage may not be monitored.

The results of the slant test did not confirm the results of the other vigour tests. The field emergence test and controlled deterioration tests had clearly shown the advantage of high phosphorus seed while the effect of nitrogen was not clear cut. But in the slant test, an increase in nitrogen produced longer roots while phosphorus did not influence root length. Thus it appears that unlike lettuce whose radicle length was highly correlated with seed vigour, the radicle length may not be a reliable guide for seed vigour in cauliflower. However, more work is required to establish correlation between root length and vigour of cauliflower seedlings.

Electical Conductivity

The measurement of electrical conductivity of electrolyte in soak water has been used in peas and beans to indicate the seed vigour. When these seeds with acceptable levels of germination are soaked in water, those yielding large quantities of electrolyte into the water emerge poorly in the field. This has been developed into a routine test for predicting the field emergence of these crops (Mathews and Powell, 1980). However, in small seeded crops this method has not been reliable guide to indicate vigour due to inconsistency of the results.

Several factors may cause high levels of leaching in seeds. The inclusion of dead seed in thelot, damaged cotyledon tissues and the cracks in the testas may contribute to the higher leaching of electrolytes and hence higher conductivity reading.

The seeds obtained from the second experiment were soaked in de-ionized water at 20^{o}C for 24 hours and the electrical conductivity reading of the soaked water indicated that nitrogen and potassium had no significant effect in influencing the reading. However, there was significant decrease in conductivity reading (signifying higher seed vigour) with those derived from the increase in phosphorus level from P_1 to P_2. Further increase in phosphorus level had no effect on conductivity reading (Table 27, Fig. 12).

There is an interaction effect of N, K with phosphorus. The third level of phosphorus combined with either the first or third level of nitrogen (N_1P_3, N_3P_3) and the second level of phosphorus combined with the second level of nitrogen (N_2P_2) had significantly lower conductivity readings than other combinations of nitrogen and phosphorus (Table 28). When nitrogen and potassium interactions were studied, N_1K_2 and N_2K_1 gave the lower electrical conductivity reading indicating that more vigorous seeds were produced at these levels than other combinations of N K (Table 29). Potassium and phosphorus interactions showed that lower levels of potassium with medium or high level of phosphorus had produced seeds which were more vigorous (i.e. had lower conductivity readings) (Table 30). Combination of medium levels of N P K had 34.2% lower conductivity reading than the low level of them ($N_1P_1K_1$).

George and Atwood (1982) reported a higher conductivity reading in aged (i.e. less vigorous) seeds of cabbage. Takayanagi and Murakami (1969) have also reported poor germinability of rape seed (*Brassica rapus* L.) with increase of exudates in soaked water. They found a close correlation between seed viability and quantity of exuded sugar from the seed. However, they did not report the correlation of seed exudation with field emergence.

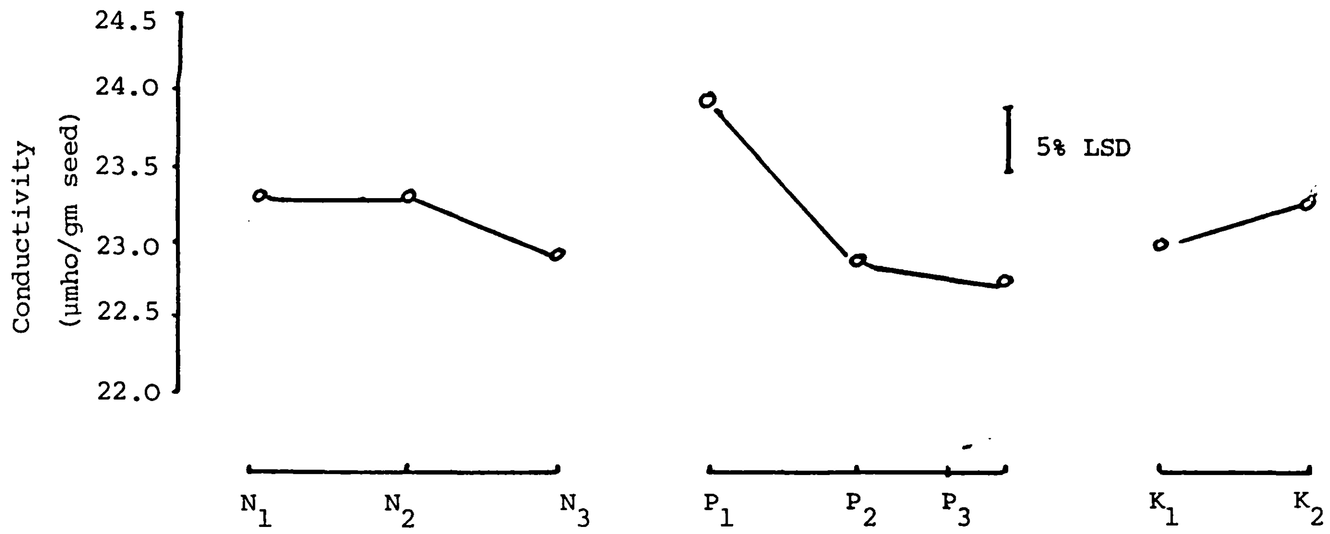

Fig. 12. Effects of N, P and K on electrical conductivity of cauliflower seed leachate

Browning (1980) had found that there was less leachate and lower conductivity reading in vining pea seeds with increase in nitrogen supply to the mother plant. In french beans, phosphorus had increased the conductivity reading and nitrogen decreased (Gavras, 1981). Although these results in cauliflower seeds appear contradictory to the other workers results with beans and peas, in both these crops higher nitrogen application was associated with higher seed vigour (as evidenced by better field emergence) and high phosphorus application had lowered the seed vigour.

The field emergence test and controlled deterioration test have indicated the effect of higher levels of phosphorus in producing more vigorous seeds in cauliflower. Thus the electrical conductivity test supplements the other vigour tests like field emergence, controlled deterioration and germination rate.

In the present study, the seed was hand harvested and care was taken to handle seeds from all treatments uniformly. The seeds which looked shrivelled, damaged or cracked through a lens, were rejected. The germination of the seed was also high (above 92%). The effect due to dead, damaged or cracked seed was thus minimized. Thus it appears that electrical conductivity readings in cauliflower seeds may give a fair indication of its vigour provided the seeds are uniformly handled. However, differences in handling method between seed lots may affect the conductivity reading.

Seedling Emergence

The seedling emergence percentage from seeds obtained from the second experiment was studied under three different conditions.

a. Seeds were sown in Levington compost in trays and grown under controlled conditions in glasshouse.

b. Seeds were sown in trays of field soil and kept under sub-optimal conditions for two weeks in the open before they were transferred to the glasshouse at elevated temperature.

c. Seeds were sown direct in the field.

The result showed that when the seeds were sown in compost in the glasshouse, nitrogen or phosphorus had no effect on seedling emergence but an increase in potassium level decreased the percentage emergence of cauliflower seed by 5.9% (Table 42). Generally the seedling emergence was high as the temperature in the glasshouse was favourable and there was comparatively better seedling emergence in compost.

When the seeds were sown in the field soil in trays and kept under sub-optimal temperature ranging from $-5^{o}C$ to $7^{o}C$ for two weeks and then brought into the glasshouse, it was observed that N, P or K had no effect on seedling emergence. However, interactions of N P and N K had a significant effect. There was an 8.4% increase in seedling emergence percentage at N_1P_3 over N_2P_3 (Table 39). The seedling emergence percentage at the first level of potassium (K_1) irrespective of nitrogen levels was generally higher than at K_2 (Table 40).

Field emergence results indicated that only phosphorus was effective in increasing the percentage of field emergence, nitrogen or potassium had no effect. There was an increase of 5.7% and 7.4% in seedling emergence at P_2 and P_3 respectively over P_1 (Table 32, Fig. 13). NP and NK interactions had also influenced the results. The seedling emergence at the lowest level of phosphorus was significantly lower at all nitrogen levels. There was an increase of 11. 2% seedling emergence at N_3P_3 than at N_3P_1. Generally there was an increase in seedling emergence at P_2 and P_3 levels (Table 33, Fig. 14).

The interaction of nitrogen and potassium levels showed that at K_2, there was an increase in percentage emergence as the level of nitrogen increased but at K_1 it decreased with increase in nitrogen (Fig. 15, Table 34). When the interaction effects of three nutrients were studied, there was no fixed pattern in their response (Fig. 16, Table 36). K_1 increased field emergence percentage with increase of phosphorus level at N_1 and N_3 but at N_2 the third level of phosphorus (P_3) decreased it. With K_2, there was an increase in field emergence as the phosphorus level increased from P_1 to P_2 but it decreased when the phosphorus level was

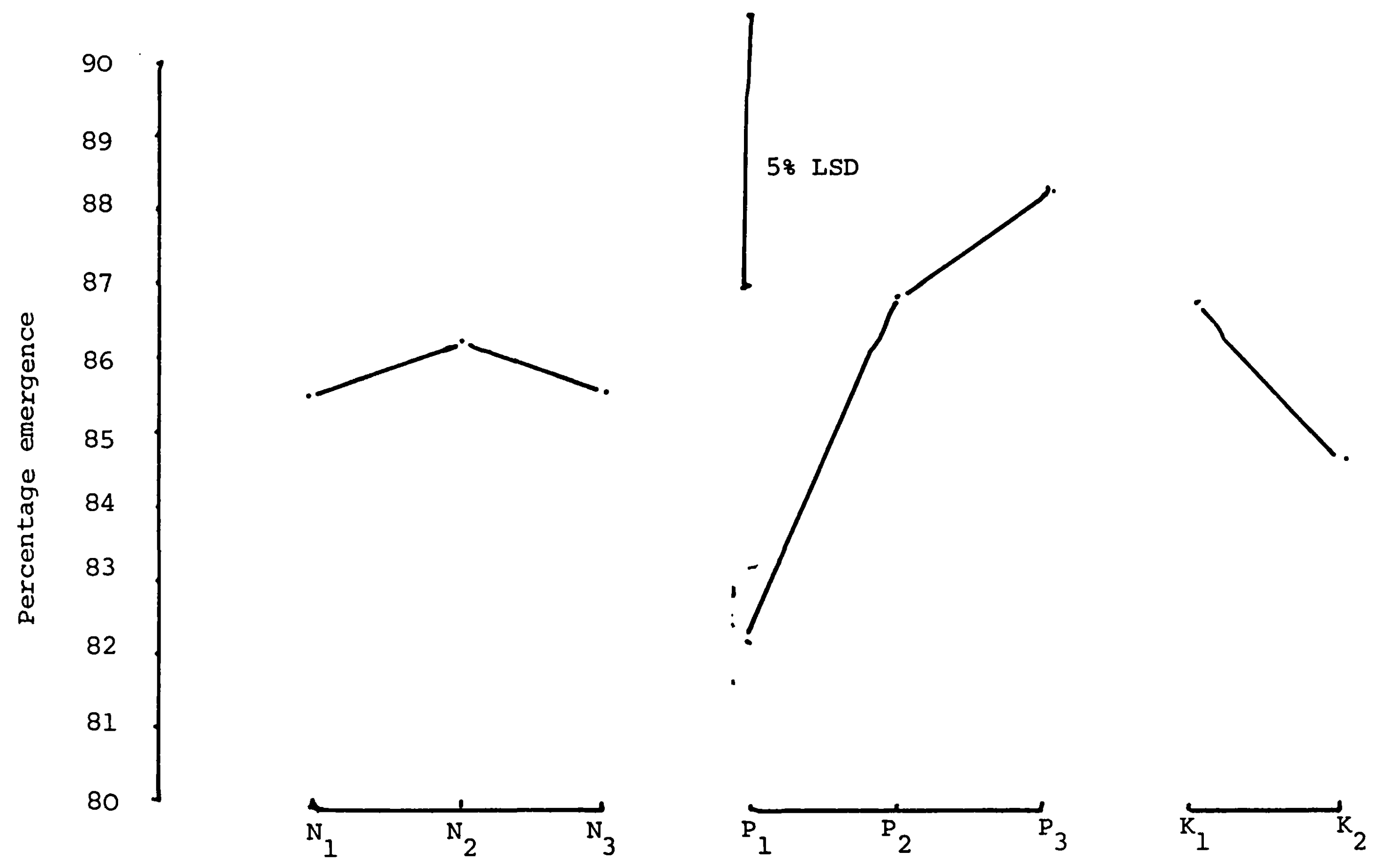

Fig. 13. N, P, K main effects on percentage field seedling emergence of cauliflower

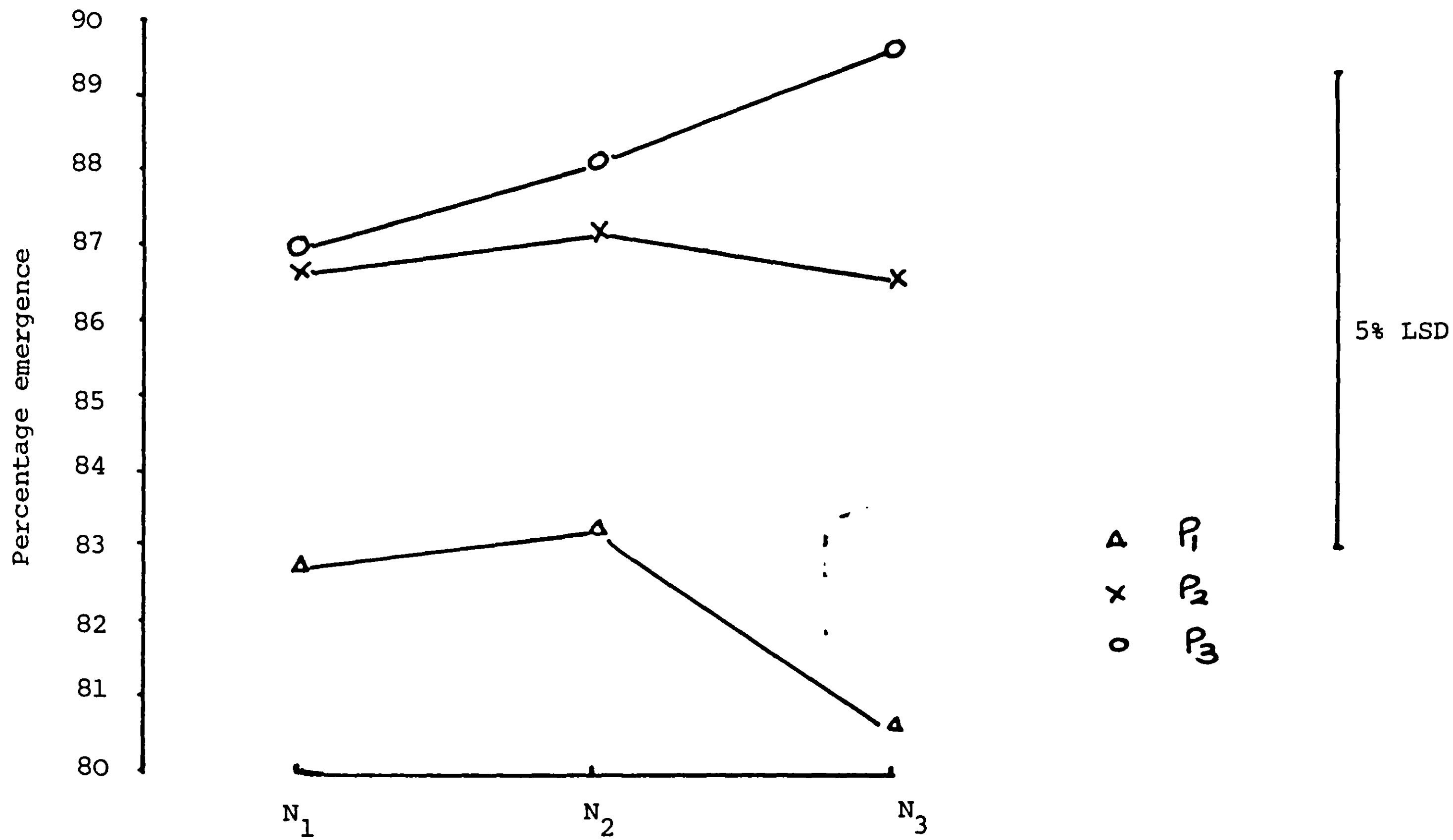

Fig. 14. Effect of N P interactions on percentage seedling emergence of cauliflower.

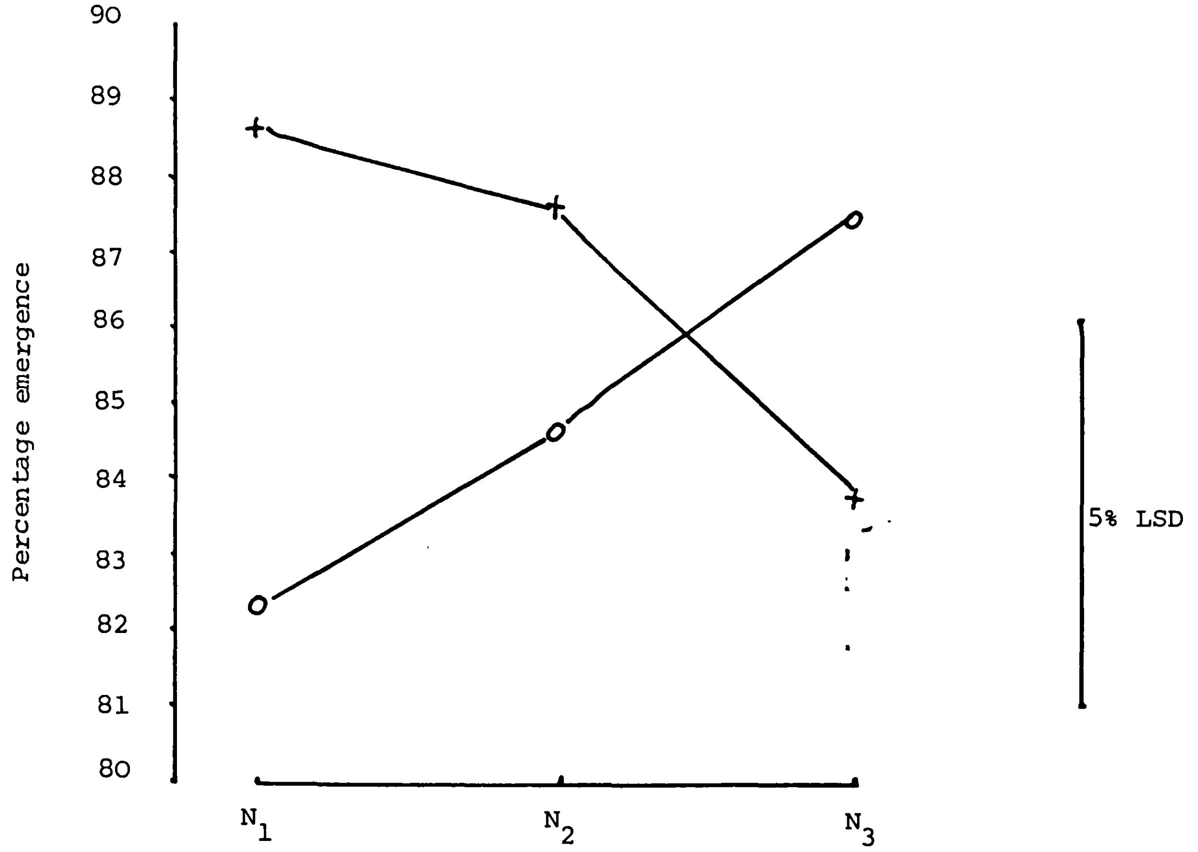

Fig. 15. Effect of N K interactions on percentage field seedling emergence of cauliflower

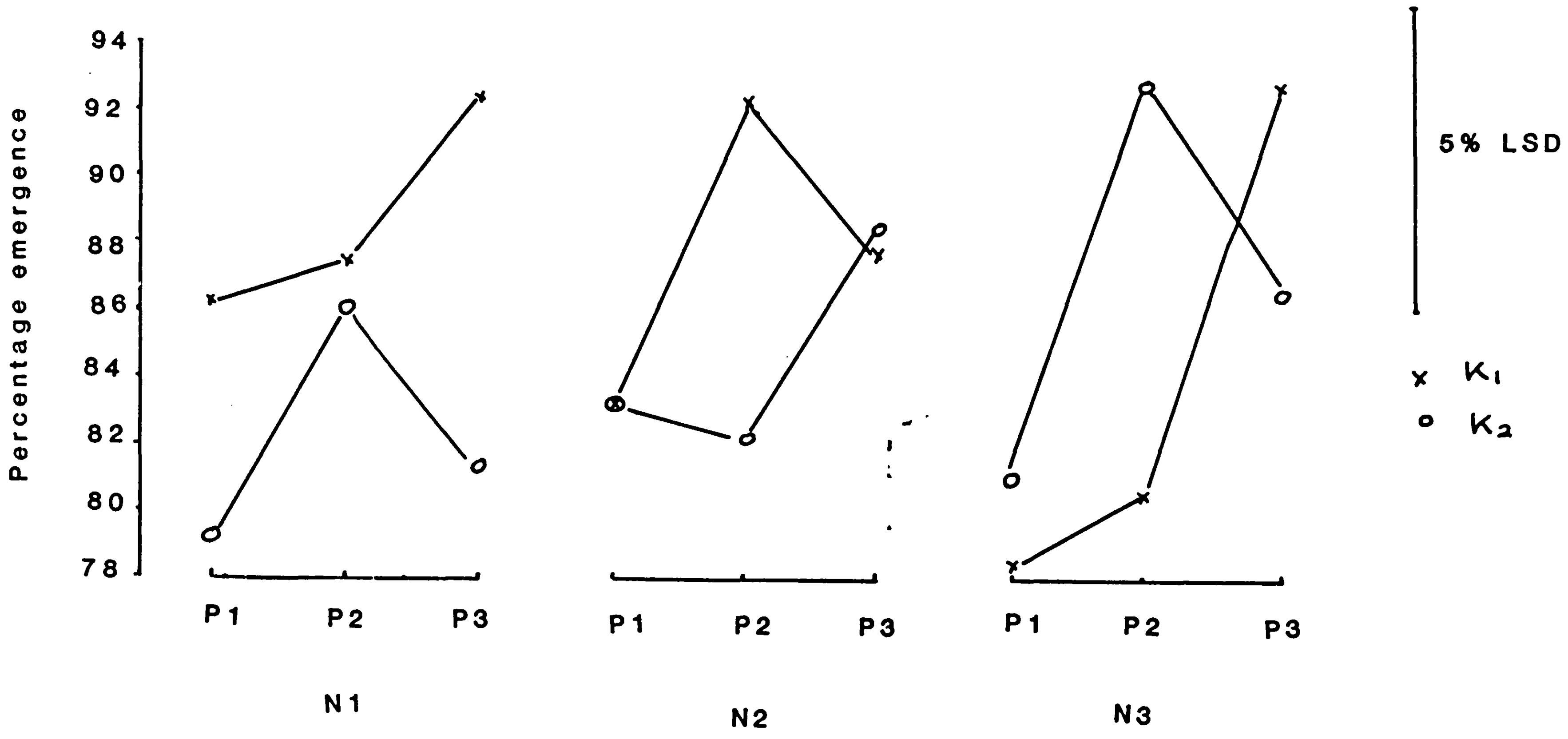

Fig. 16. Effect of N P K interactions on percentage field emergence of cauliflower

further increased at N_1 and N_3. At N_2, on the other hand, there was an increase of emergence at the P_3 level.

In the third experiment, nitrogen had no effect on the field emergence percentage (Table 64). Seeds obtained from all the four levels of nitrogen had a similar field emergence percentage.

The seeds obtained from the fourth experiment showed that when sown in peat in glasshouse conditions, phosphorus had no effect on the seedling emergence (Table 80).

With mustard broad leaf, there was a 19.5% and 14.5% decrease in seedling emergence when the nitrogen level was increased from N_1 to N_2 and N_3 respectively. Phosphorus had no effect (Table 91). Nitrogen and phosphorus interactions effect was also significant. There was 35.5% lower seedling emergence at N_2P_2 than at N_1P_1 (Table 92). This can be explained by the fact that the soil used for this experiment had relatively high initial phosphorus content (phosphorus index of 6). Because of higher initial phosphorus, addition of phosphorus had not increased the emergence percentage. Nitrogen has been found to increase the seed yield but it need not accompany higher quality. Ahmed (1982) has also reported an increase in yield due to high nitrogen level was accompanied by decrease in seed vigour of onion.

Heydecker (1965) stated that the emergence of seedling in a sub-optimal environment has been ascribed to seed vigour. Perry (1967) showed that levels of seedling emergence in the field are determined by soil type and environmental conditions as well as inherent vigour of the seed. The emergence test under three different conditions showed that field emergence is a better indication of seed vigour. The seed emergence in compost in the glasshouse where a favourable temperature was maintained produced very high emergence. Similarly, sowing seeds first in field soil under sub-optimal conditions and then transferring them to favourable conditions also failed to produce desired measurement of seed vigour.

Controlled Deterioration

Seed lots which show similar germination levels in the laboratory may possibly have different stages of deterioration which will be demonstrated by different levels of vigour. Where vigour differences exist between seed lots, subjecting them to further deterioration at high temperature and moisture for a certain period of time would result in differences in germination percentage, which would be indicative of vigour or deterioration stage of seeds. Roberts (1973) has demonstrated the precise nature of the relationship between the rate of decline in viability and the moisture and temperature at which the seeds are stored. A close relationship between germination after accelerated ageing in soyabean and field emergence has been demonstrated by Delouche (1973). Mathews (1980) has also reported a high correlation between germination of some small seeded crops after controlled deterioration and field emergence.

The seeds obtained from the experiments had different levels of nutrient treatments and to assess the differences in vigour of the seed, they were subjected to high temperature (45^{o}C) and moisture (20% RH) for a period of 60 hours and the germination percentage of deteriorated seeds ascertained.

The seeds from the second experiment indicated that the nitrogen or potassium main effect was not significant in influencing the germination percentage after controlled deterioration. Only phosphorus at the third level (P_3) produced seeds with relatively higher germination (significant at 5% level; Table 22).

However, nitrogen and potassium had affected germination after controlled deterioration if they were applied to the plant in conjunction with phosphorus. The germination percentage at N_1P_3 and N_3P_2 was 5.3% higher than at N_1P_1. Similarly nitrogen and potassium interaction had a significant effect. Seeds produced at N_3K_1 and N_1K_2 had 5% and 4.7% higher seed germination after controlled deterioration than at N_1K_1 (Table 24). The combination of lower levels of phosphorus and potassium (N_1K_1) had a significantly lower germination percentage (i.e. 5.6%) than at higher percentage of phosphorus and potassium (P_3K_2; Table 25). But when all nutrients were present, there was no trend in germination percentage. $N_1P_1K_1$, $N_2P_2K_2$ and $N_3P_1K_2$ showed a lower germination percentage while $N_1P_1K_2$, $N_1P_3K_2$, $N_3P_1K_1$, $N_1P_2K_1$ showed significantly higher germination percentage (Table 26).

In the third experiment which was conducted in the field to study the effect of nitrogen levels only on the seed quality, it was observed that an increase in nitrogen levels had no effect on seed germination after controlled deterioration (Table 65). This result is generally in conformity with the result of the second experiment.

Similarly the fourth experiment indicated that the effect of the first two levels of phosphorus was similar but there was higher germination percentage at P_3 and P_4. The increase in germination percentage from P_1 to P_3 and P_4 was 16.1% and 11.6% respectively.

It is seen from the results that while the nitrogen and potassium main effect had no influence on seed germination after controlled deterioration, the interactions of N and K with P significantly affected germination. The results of these experiments generally indicate that combinations of lower levels of N, P or K performed poorly (i.e. had poor germination percentage). There was not any trend in the result to indicate which levels of nutrients would perform best.

Phosphorus was found in both second and fourth experiments to have a significant effect on germination.

Ahmed (1982) reported a slight decrease in germination of onion seeds after controlled deterioration as the nitrogen level was increased but potassium had no effect. With phosphorus, the medium level decreased the germination percentage but the higher level increased it. Osman (1982) also found an increase in germination percentage of pepper seed after controlled deterioration with an increase in phosphorus levels which is in agreement with the present study. However, in pepper, an increase in both nitrogen and potassium increased germination after controlled deterioration. It was reported by Osman (1982) that in pepper increased levels of N P K had improved seed vigour as confirmed by deterioration tests, emergence test, seedling evaluation test. Conversely in cauliflower, an increase in potassium generally decreased seed vigour while an increase in nitrogen was not accompanied by an improvement in seed vigour.

When the seeds are stored, they start deteriorating, the rate of deterioration being the main function of temperature and moisture. However, the seeds which have the higher vigour should not deteriorate at the same rate as less vigorous seeds. That is more vigorous seeds would maintain viability longer under similar storage conditions. The controlled deterioration test at elevated temperatures and moisture gives a fair indication of seed deterioration during storage. It appears from the controlled deterioration test that cauliflower seeds produced at higher levels of phosphorus should maintain higher viability during storage than those seeds produced at lower phosphorus levels. Nitrogen and potassium had no effect but in combination with different levels of phosphorus, the seed vigour was influenced as observed by higher percentage germination after controlled deterioration.

Seedling Evaluation

The seeds obtained from the different experiments were grown in compost in the glasshouse and the rate of seed germination (Ellis and Roberts, 1980; Maguire, 1982), percentage normal vigorous seedlings (Tonkin, 1969) and the mean dry weight of seedlings were determined

a. Germination rate

The seeds which take less mean time to germinate or emerge are generally more vigorous. The result of the second experiment showed that an increase in nitrogen level from N_1 to N_2 produced seeds which took less mean days to emergence. Seeds produced at N_3 behaved similarly to N_1 seeds. With phosphorus, seeds produced at P_2 took least mean days followed by P_3. The potassium treatments had no effect on mean days to emergence (Tables 43, 44). N P interactions was also significant.

In broad leaf mustard (experiment 5), the seeds obtained from motherplants receiving higher nitrogen levels took longer to emerge than seeds produced at lower nitrogen levels. This provided a general indication that an increase in nitrogen decreased the seed vigour of mustard broad leaf.

The seeds which take less days to emerge had an advantage over those seeds which took comparatively longer to emerge. Such seedlings get the chance to establish earlier. However, in all the experiments, the differences between different treatments were of less than half a day and so it appears that such an advantage may not have practical significance to a grower.

The germination rate calculated according to Maguire (1962) also gave a similar trend of seed vigour as obtained by mean days to emergence (Ellis and Roberts, 1980).

Abdul-Baki and Anderson (1972) have reported a decline in rate of germination with loss of vigour in ageing seeds. In such seeds, the rate of germination should provide a better guide for vigour. The seeds which are comparatively fresh have generally shorter mean days to emergence than the aged or deteriorated seeds. The seeds in the present experiment were fresh and took only 4 - 6 days for most of the seedlings to emerge. Thus the differences between treatments were very small, although significant.

b. Normal vigorous seedling

The seedlings which were 25% or more by weight than the heaviest seedling were considered normal vigorous seedlings (Tonkin, 1969). Neither N P K main effect nor the effects of NP, NK, PK interactions had shown significant differences in producing normal vigorous seedlings (Experiment 2). However, NPK interaction effects were significant (Table 49, Fig. 17). The table shows that generally there is an increase in the percentage normal seedlings at the lower level of potassium from P_1 to P_2 at all nitrogen levels but it decreased at P_3. With higher levels of potassium, normal seedling percentage increased with an increase of phosphorus at N_1 but decreased at N_2. In the third and fourth experiments, nitrogen and phosphorus had no significant effect in producing normal vigorous seedlings (Tables 63, 81).

With mustard broad leaf (experiment 5), there was a 21.8% and 13.7% decrease in the percentage of normal seedlings as the level of nitrogen is increased from N_1 to N_2 and N_3 respectively (Table 97). However, with phosphorus, only the second level showed a significant decrease in normal seedling percentage. Nitrogen and phosphorus interactions were highly significant. Seeds

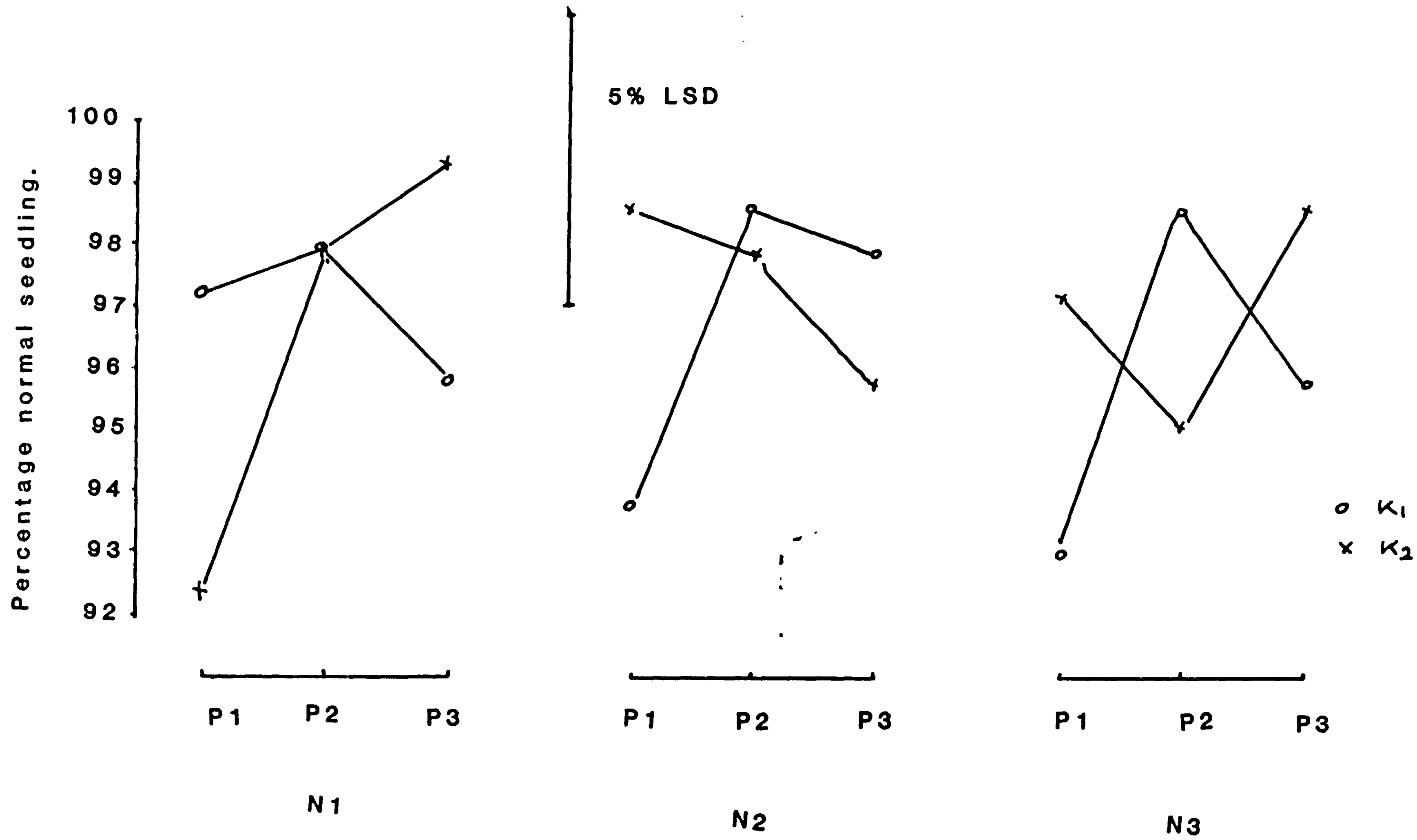

Fig 17 Effect of NPK interactions on percentage of normal vigorous seedlings.

produced at N_1P_1 had 73.7% higher normal seedling percentage than seeds produced at N_2P_2 (Table 98). There is a general decrease in normal seedlings with the increase in nitrogen level at P_1. But at the higher levels of phosphorus, only the second level of nitrogen produced a lower percentage of normal seedlings.

It is concluded from this result that the production of normal vigorous seedlings is not an indication of seed vigour in cauliflower. Although care was taken to minimize the environment effect on different treatments, it is possible that competition for light, water and nutrients may have affected the results. The seedlings were left in the trays in the glasshouse for 4 weeks and by that time the seedlings had started shading adjacent plants. Any slight change in the environment such as light intensity or temperature may affect the result. But in mustard broad leaf, the seedlings which emerged earlier had an advantage over other seedlings and they showed more vigorous seedlings throughout the crop growth (4 weeks). Here the general growth of the seedling was not as luxuriant as in cauliflower and so the competition for light, water or nutrients had probably not started as they did in the case of cauliflower seedlings. Thus the result is a clear indication of seed vigour. In cauliflower, either the seedlings should be weighed before they started to shade each other or they should be more widely spaced to minimize inter-plant competition for light and nutrients. In mustard broad leaf, the first level of nitroen is sufficient to produce more vigorous seedlings than higher levels. The initial high level of phosphorus in the soil may be the reason why application of this nutrient showed no significant differences in producing normal seedlings.

c. Seedling mean dry weight

The seedlings were dried at 100°C for 48 hours and the mean dry weight calculated. Neither in experiment 2 nor experiment 5 did the mean dry weight of seedlings give any indication of seed vigour. The result produced at various treatments were similar. It was thought that the seeds which were more vigorous should produce larger plants and an increase in mean dry weight. But the results of these experiments showed that the differences in mean dry weight were small and therefore of no practical significance as a guide for determining the seed vigour differences.

Vigour tests for graded seeds

The cauliflower seeds obtained from the third and fourth experiments were divided into grade A, grade B, grade C and grade D seeds while mustard broad leaf seeds from the fifth experiment was divided into grade A and grade B seeds, as defined on pages 136 and 147.

a. Standard germination of cauliflower seed

The results in Table 57 indicate that there is an increase in germination percentage from 92.5% in grade C seeds to 96.5% for grade B and D seeds and 98% for grade A seeds. However, the differences were not statistically significant. But the results indicate the germination advantage of large seeds over small.

b. Seedling emergence

The seeds from the third experiment were sown in the field and the result indicated that there were more seedlings which emerged from grades A and B seeds. The grade C seed had 15.5% lower seedling emergence than grade A seed (Table 64a). In mustard broad leaf also, grade A seeds showed superiority over grade B seeds. There was 12.6% increase in seedling emergence by grade A seeds.

These results indicate that for field emergence seeds less than 1.7 mm are less reliable than large seeds. With cauliflower, seed size above 1.70 mm or ungraded seeds which has a higher percentage of larger seeds, are better than grade C seeds. The difference between grade B and D seeds are not significant. The different grades of seeds produced by a plant may be due to the position of the inflorescence which reflects differences in flowering time and nutrition of the developing seeds. In cauliflower and mustard broad leaf smaller seeds may have been formed late in the growing season and may not get conditions conducive to full maturity. Normally such seeds perform poorly under field conditions. Many workers have suggested the importance of medium and large sized seeds for increased germination and field emergence. (Ibrahim (1977) with brussels sprouts and kale; Hewston (1964) with cauliflower; Joubert and Rappord (1970) for brussels sprouts and cauliflower; Ahmed and Zuberi (1973) with rape and Desi *et al.* (1965) with turnip have clearly shown that large or medium sized seeds perform better in germination and emergence than the smaller sized seeds.

c. Normal seedling

The seedlings which were 25% or above of the heaviest seedling were regarded as normal vigorous seedlings (Tonkin, 1969). The seeds from the third and fifth experiments indicated that seedling produced small seeds had significantly lower percentage of normal vigorous seedling (Tables 63, 97). With cauliflower grades A, B and D seeds performed similarly, grade C seeds produced seedlings which were 9.8% lighter than seedlings produced by grade A seeds. Similarly with mustard broad leaf the seedlings produced from grade B seeds were 17.4% lighter than seedlings produced from grade A seeds. In mustard broad leaf in which the leaves of the commercial vegetative crop are consumed and thus the large seed will have an advantage over smaller seeds in crop yield.

d. Root length

Cauliflower seeds obtained from the nitrogen experiment (experiment 3) and phosphorus experimant (experiment 4) were grown in darkness to measure their root length after 48, 72 and 96 hours of imbibition. Grade B and C seeds obtained from the second experiment had produced significantly longer roots than other grade seeds when the root was measured after 48 hours; only grade B seeds showed longer roots after 72 hours but the differences between all seed grades were not significant after 96 hours (Tables 58, 61, 62, Fig. 18). However graded seeds from experiment four showed no such differences either at 48, 72 or 96 hours after imbibition (Tables 73, 75, 77). The root length measurement in determining the cauliflower seed quality was not consistent. There was not any trend in the result. It was observed that generally smaller seeds such as grade C and B seeds germinated earlier than grade A or D seeds and this initial advantage in root length is indicated in the result. However, the root growth in seeds from other grades catch up and the differences are not significant after 96 hours of root growth. Atwood (1980) had also found that the differences in root length of cabbage seedlings of different vigour were less significant after 72 hours. He suggested that the rate of germination may be of more importance in vigour determination than actual root growth. It is concluded from the result that further work is required to establish a relationship between root length and vigour of cauliflower seeds.

e. Curd yield

The graded seeds from the third experiment were sown in

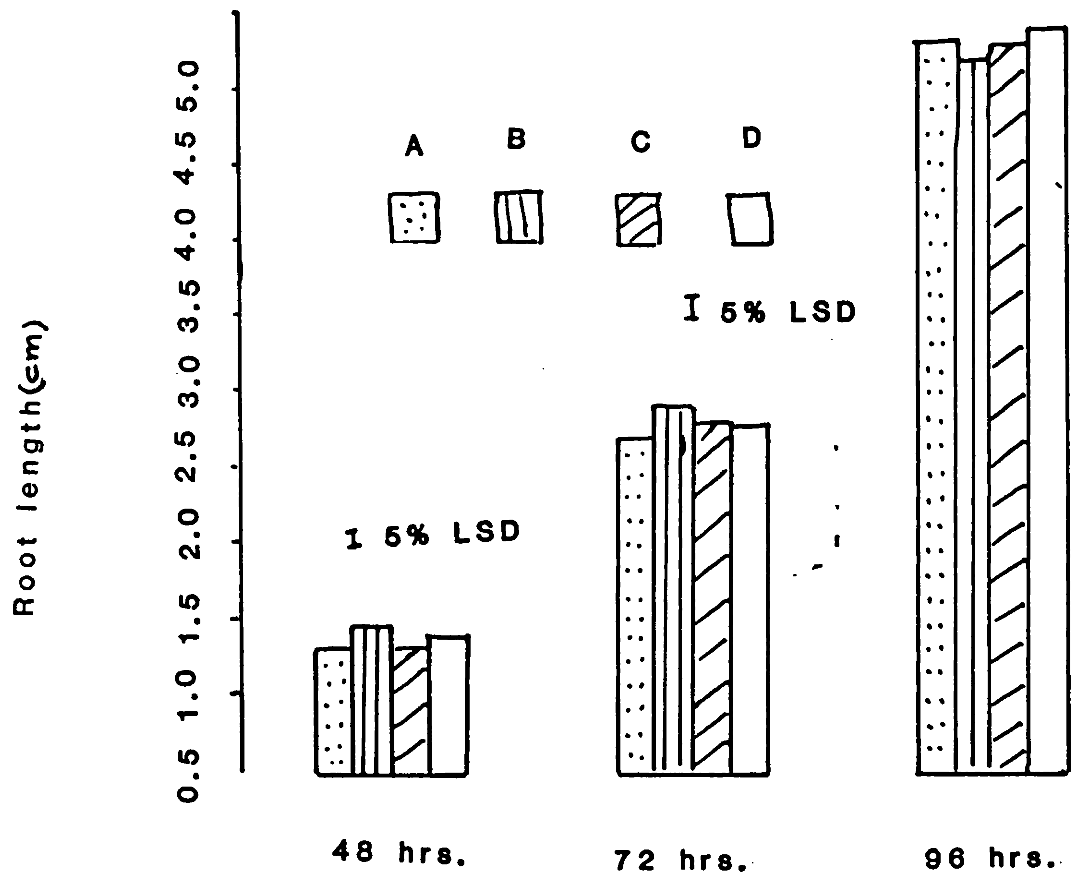

Fig 18 Effect of graded seeds on root length after 48,72, and 96 hours.

soil in a plastic tunnel to study their effects on cauliflower curd yield.

The result (Table 66) showed that although grade D seeds had produced highest and grade C the lowest curd yield (a difference of 18.2%), the difference did not reach a significant level. The different seed quality tests have indicated grade C seed to be of lower quality (vigour) than other grade seed. However, when the yield of curd was considered, the differences between the effects of different grade was not high. Although the large seeds have initial advantage in emergence and seedling establishment, the competition between plants for nutrients, water and light commence sooner in crops like cauliflower where the large spread of leaves obstruct the light. When the crop was left in the field for longer periods until curd maturation, the plants from smaller seeds "picked up"and the differences between the effect of large and small seeds was not significant. Hewston (1964) reported an increase in curd yield of cauliflower cv. 'Delta' (early cultivar with a relatively low plant height and small spread). But in other cultivars such as 'Whitechief' he found no difference in curd yield due to seed size as the large plant spread helped inter-plant competition earlier. The advantage of large seed of sprouting broccoli in getting higher early yield has been reported by Tompkin (1966) but when the plant was left longer in the field, total yield was not affected by seed size. Thus it appears that large or medium seeds may be helpful for early establishment of plants but need not significantly influence yield if left longer in the field.

Conclusion and suggestions for future work

The following conclusions were drawn from the results of the present study.

1. The application of nitrogen above 50 kg/ha to cauliflower plants grown for seed production in glasshouse conditions did not increase seed yield but under field conditions, three split applications of nitrogen up to 250 kg/ha had steadily but insignificantly increased the yield. In soils with low fertility or the crop supplied with insufficient levels of nitrogen, cauliflower tends to button, a physiological disorder where very small curds are formed. Such buttoned curd results in very low seed yield. The nitrogen application should be split into two or possibly three applications to avoid buttoning and too luxuriant vegetative growth. Split applications would ensure better utilization of this nutrient. Application of all nitrogen at one time may encourage rotting and thus affect the seed yield. Where sufficient phosphorus and potassium were present in the soil, their application did not increase the seed yield. In mustard broad leaf nitrogen increased seed yield but application of phosphorus had no effect.

2. Increase in seed vigour is not necessarily related to

nitrogen application to the mother plant. The seed from the second experiment showed increased root length with increase in nitrogen level. All other tests had failed to show a significant effect on cauliflower seed yield. However in mustard broad leaf, increase in the level of nitrogen decreased the seed quality.

3. While the application of phosphorus has not affected the seed yield of cauliflower or mustard broad leaf, there is an indication that an increase in phosphorus levels gives high vigour seeds of cauliflower. There is an increase in percentage germination, 100 seed weight, percentage field emergence, germination percentage after controlled deterioration and decrease in electrical conductivity reading and mean time to emergence as the level of phosphorus is increased. This is shown in the seeds from the second experiment. The vigour test result of the fourth experiment did not indicate a clear trend. When the phosphorus level in the soil was high, additional phosphorus had no effect on seed quality of mustard broad leaf. Different levels of phosphorus applied to soil of a relatively low phosphorus status or in peat sand media would give an indication of optimum level of phosphorus for the best quality seed of mustard broad leaf.

4. An increase in the potassium levels has decreased the germination percentage, 100 seed weight, and increased the root length but had no significant effect on the conductivity

reading, percentage field emergence, normal seedling percentage or germination after controlled deterioration .

5. There was an interaction effect of NP, NK, PK and/or NPK on percentage germination, percentage field emergence, conductivity reading, seedling evaluation but not on root length. Generally higher levels ofphosphorus with medium levels of nitrogen gave increased germination and emergence. Seeds at K_1 had performed better with increase of phosphorus level than at K_2.

6. Standard germination, slant test or seedling evaluation tests were not a better guide for field emergence. The conductivity test, germination after controlled deterioration, rate of seedling emergence were a comparatively better guide to indicate the field emergence of cauliflower.

7. Medium or large sized seeds of cauliflower and mustard broad leaf performed better in most of the seed quality tests. For better field performance, small sized seeds of these could be graded out and discarded before marketing the seed lot. In cauliflower large sized seed (above 2.00 mm) did not show consistent superiority over medium (1.7 - 2.00 mm or ungraded) seeds. The percentage of grade C (below 1.7 mm) seed in cauliflower seed lot ranged from 6% to 22%.

8. In a cauliflower crop grown in containers with sand peat media, fritted EM 255 applied at the rate of 0.375 gm/litre

does not provide sufficient boron and the crop should be supplemented with extra boron either as a base dressing or as a foliar spray. Cauliflower is susceptible to boron deficiency and the symptoms show especially at the curd maturation stage by which time the effect is irreversible. The additional application of boron in the young plant would be expected to prevent boron deficiency symptoms.

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