EFFECT OF HARVESTING AND GROWTH REGULATOR ON SEED YIELD, QUALITY AND VIGOUR IN CUCUMBER (*Cucumis sativus* L.)

By

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DECLARATION

I hereby declare that this thesis entitled "**Effect of harvesting and growth regulator on seed yield, quality and vigour in cucumber (*Cucumis sativus* L.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

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CERTIFICATE

Certified that this thesis entitled "**Effect of harvesting and growth regulator on seed yield, quality and vigour in cucumber (*Cucumis sativus* L.)**" is a record of research work done independently by Ms. Sindu, B. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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EXTERNAL EXAMINER

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LIST OF ABBREVIATIONS

CD	Critical difference
cm	Centimetre
d.a.a	Days after anthesis
DAF	Days after flowering
DAS	Days after sowing
et al.	and others
Fig.	Figure
FYM	Farmyard manure
g	Gram
GA	Gibberellic acid
ha	Hectare
kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
m	Metre
mg l^{-1}	Milligram per litre
MH	Maleic hydrazide
NAA	Naphthalene acetic acid
ppm	Parts per million
SE	Standard error of mean
TIBA	Triido benzoic acid
VI	Vigour index

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INTRODUCTION

1. INTRODUCTION

Of the gifts of nature that enliven our day to day life, vegetables constitute an important group. Vegetables play an important role in human nutrition by providing carbohydrates, proteins, minerals and vitamins. India is the second largest producer of vegetables in world next to China with a production of 66.5 million tonnes from an area of 5.08 million hectares. But the demand for vegetables in our country is 110 million tonnes. Vegetable production in Kerala is 27 lakh tonnes from 2.09 lakh ha. Productivity of vegetables in India is only 13 t/ha as against an average of 25 t/ha in countries like China (Chadha, 1999).

Seed is the basic and most remunerative input in crop production especially in vegetables. Of the various factors affecting the productivity of vegetables, availability of quality seed is of major concern. The major cause for the low productivity of vegetables is the limited availability of good quality seeds.

The present requirement of vegetable seeds in the country is 30000 t per annuum of which only 20200 t is supplied by authorised agencies (Seshadiri, 1993). In Kerala the requirement is 72 t out of which only 20 to 25 per cent is supplied by authorised seed agencies (Kerala Agricultural University, 1991). Due to the non-availability of good quality seeds or due to financial constraints farmers are compelled to use their farm saved seeds which are collected from the worst and last formed fruits and hence inferior in quality. Such practices led to a rapid decline in the productivity of vegetables.

Hence vegetable seed yield has to be stepped up from the present level to ensure adequate supply of seeds.

The best alternative to tackle this problem is to combine vegetable production and seed production. Combining vegetable production with seed production may be possible as the periodic removal of early formed fruits as vegetable stimulates the growth of crop and thereby increasing the bearing capacity. So a good yield of quality seeds along with some vegetables can be obtained by this practice instead of using the leftovers for seed.

Recent findings in seed technology research have indicated that the use of growth regulators especially ethephon is useful in increasing the seed yield of vegetables without affecting the quality of the seeds. Besides, the use of growth regulators increases the fruit setting and yield of fruits.

In addition to all these factors the seed maturity at the time of fruit harvest is an important factor that determines the quality of the seed. Harvesting the fruits at optimum stage of physiological maturity not only minimises the loss in vigour and viability but also reduces the damage due to insect and fungal attack. Pre-harvest factors such as degree of seed maturity influence the germinability and vigour which inturn affect the potential longevity of seeds.

Post harvest storage of curcurbit fruits for seed purpose is an age-old practice followed by farmers. Seeds continue to mature in fruits which were harvested before ripening and stored under ambient conditions (Krishnaswamy, 1991). Eventhough fruits are harvested at immature stage, good quality seeds with high germination potential and vigour will be obtained by storing the fruits for few days.

However the scientific information available on these aspects is much limited and hence the present investigation was conducted in cucumber with the following objectives.

1. To assess the effect of number of vegetable harvests on fruit yield, seed yield and seed quality.

2. To study the effect of growth regulators on seed yield and quality.

3. To study the economics of the different treatments.

4. To standardise the physiological stage of maturity in cucumber for quality seed production.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In vegetables among the several factors which account for the better quality of seeds, vegetable harvests, use of growth regulators, and stage of maturity of fruit at the time of harvest and storage of fruits intact before seed extraction are found to have a profound influence. The available literature on these aspects are reviewed in this section.

2.1 Effect of vegetable harvests

Since there are only limited research efforts on the effect of vegetable harvests on seed yield and quality in cucurbits, the information available on other crops are also included.

2.1.1 Effect of vegetable harvests on growth characters

Significant influence of vegetable harvests on plant growth has been reported by several authors.

Velumani and Ramaswamy (1980) in an experiment to find out the effect of vegetable harvests on plant height and seed yield in bhindi observed decrease in height of plants when all fruits were left to mature for seed and increase in height when the first formed twelve fruits were harvested as vegetable. Similar increase in plant height with increasing number of green fruit picking was also reported by Wankhade and Morey (1981) in chilli.

In bhindi stunted growth of plant was observed when all the fruits were left to mature for seed purpose without green fruit harvest (Garris and

Hoffmann, 1946 ; Shanmughasundarum, 1950 ; Kolhe and Chavan, 1967 ; Kamalanathan *et al.*, 1968 ; Bhuibar *et al.*, 1989). However, Khan and Jaiswal (1988) reported that green fruit pickings had no effect on the plant height of bhindi.

Sheeba (1995) reported that plant height at 90 DAS varied significantly with vegetable harvests. Six vegetable harvest treatment recorded the highest value of plant height which is superior to four, two and zero vegetable harvests in bhindi. Similar results were reported in bittergourd by Devi (1999).

2.1.2 Effect of vegetable harvests on fruit yield and yield attributes

2.1.2.1 Yield of green fruits

Green fruit yield was proportionately high in bhindi when more vegetable harvests were done (Madhava Rao, 1953). Grewal *et al.* (1974) reported a linear increase in the number as well as weight of green fruits per plant and a decrease in length of pods with each picking in bhindi. Bhuibar *et al.* (1989) observed that when zero, one, two, three and four pickings of green fruits were done, the highest yield of green fruits was obtained with four pickings in bhindi.

Cucumber, summer squash, bittergourd and other cucurbits grown for their immature fruits are more productive if the fruits are harvested frequently and not allowed to become large. Large fruits act as a sink for nutrients and inhibit the development of additional fruits on the plant (Robinson and Decker-Walters, 1997). Devi (1999) reported that the bearing capacity of bittergourd plant is improved by frequent picking of green fruits.

The green fruit yield is thus found to increase due to vegetable harvests.

2.1.2.2 Yield of mature fruits

Maximum number of dried fruits per plant was observed with three green fruit pickings in bhindi (Pandey *et al.*, 1976). Khan and Jaiswal (1988) reported that the number and weight of dried fruits per plant were significantly influenced by fruit picking over no picking and the maximum weight and number of fruits per plant were obtained under two pickings in bhindi. Similar results were also obtained by Bhat and Singh (1997) in bhindi. According to Devi (1999) ripe fruit yield increased upto two vegetable harvests in bittergourd and maximum yield of mature fruit was obtained for the treatment with two vegetable harvest.

But Sheeba (1995) reported highest mature fruit yield when no green fruit picking was done.

2.1.2.3 Total number of fruits per plant

In bhindi plants in which maximum number of fruits were harvested for vegetable produced more number of fruits (Shanmughasundaram, 1950). Similar results were reported by Perkins *et al.* (1952), Grewal *et al.* (1974) and Velumani and Ramaswamy (1980). Kolhe and Chavan (1967) concluded that allowing fruits to mature right from the beginning for seed reduced the number of fruits to one third. Tyagi and Khandelwal (1985) observed that three pickings produced higher number of fruits over the control of no fruit picking in bhindi.

Thus it is evident that periodical removal of green fruits stimulates fruit production in vegetables.

2.1.3 Effect of vegetable harvests on seed characters

2.1.3.1 Number of seeds per fruit

Rode (1979) observed the maximum number of seeds per fruit in bhindi plants which were left to mature for seeds without vegetable harvests. Similar results have been obtained in bhindi by Velumani and Ramaswamy (1980), Deshmukhe and Tayde (1986) and Bhuibar *et al.* (1989). Devi (1999) has also reported similar results in bittergourd.

Wankhade and Morey (1981) reported that in chilli green fruit picking had no significant effect on the number of seeds per fruit. The same trend was observed by Khan and Jaiswal (1988) in bhindi. Similar result was reported by Sheeba (1995).

2.1.3.2 Weight of seeds per fruit

The weight of seeds per fruit was found to be superior with zero or two green fruit pickings compared to four, six, eight, ten and twelve fruit pickings in bhindi (Velumani and Ramaswamy, 1980).

In chilli no significant influence of green fruit picking on the weight of seeds per fruit (Wankhade and Morey, 1981).

2.1.3.3 1000 Seed weight

Grewal *et al.* (1973) observed significantly lower 1000 seed weight in plants where three to four green fruit pickings were done. However the same authors observed no appreciable difference in 1000 seed weight due to one or two green fruit pickings. Similar reports on the progressive decrease in seed weight with increase in the number of fruits harvested for vegetable were given by Velumani and Ramaswamy (1980), Khan and Jaiswal (1988) and Bhuibar *et al.* (1989).

Sheeba (1995) observed that the effect of vegetable harvest on 1000 seed weight was not significant, however two vegetable harvests recorded the highest value in bhindi. Significant influence of vegetable harvests on 100 seed weight in bittergourd was reported by Devi (1999). Two vegetable harvests had the highest value which was on par with zero vegetable harvest.

2.1.3.4 Seed yield

In cucumber the quantity and quality of seeds were best when seeds were collected from the first formed fruits on the plant. With a rise in number of fruits per plant (i.e., greater than nine to 15 fruit) seed weight tend to decrease, but other quality criteria were unaffected. Within the above range seed bearing fruits per mother plant and seed yields from single fruit were not dependent on the number of fruits per plant or on their size (Men'kova, 1974). In bhindi, Pandey *et al.* (1976) observed a significant increase in seed yield upto two pickings of fruits and the yield from three green fruit pickings was on par with the control of no fruit picking. Four pickings of fruits significantly reduced seed yield. In bhindi seed yield was significantly high when the first formed two fruits were harvested as vegetable and this was on par with no green picking (Velumani, 1976). Khan and Jaiswal (1988) also obtained maximum seed yield with two pickings of green fruits followed by one, zero and three pickings.

Two green fruit pickings significantly increased the number and weight of dried fruits and seed yield in bhindi (Singh and Kanwar, 1995). Sheeba (1995) reported that in bhindi highest seed yield was observed with zero vegetable harvest which was on par with two vegetable harvests. Significantly higher seed yield was also recorded with two green fruit pickings by Bhat and Singh (1997). Devi (1999) reported that in bittergourd seed yields increased significantly upto two vegetable harvests.

2.1.3.5 Seed quality

Boose (1966) reported that limiting the number of fruits left for seed production is one of the ways of improving the quality of seeds in cucumber. Seeds from early formed fruits gave a higher germination percentage in cotton (Selvaraj and Ramaswamy, 1976) and in chilli (Murthy, 1979 and Dharmatti and Kulkarni, 1988).

Grewal *et al.* (1973) found that plants in which no green fruit picking was done gave the highest germination percentage in bhindi. Asokmehta and Ramakrishnan (1986) reported that the seeds of chilli variety CO-1 from second and third pickings showed superiority after 12 months of storage. In bhindi germination percent, 1000 seed weight, 100 seed volume, seed protein and seed moisture content were not significantly influenced by vegetable harvests while seedling root and shoot lengths and vigour index values were better for two vegetable harvest treatments (Sheeba, 1995). Devi (1999) reported that germination percent is not significantly influenced by vegetable harvests, but the 100 seed weight was higher for two vegetable harvest treatments which was on par with zero vegetable harvests.

2.1.3.6 Seedling characters

Velumani (1976) observed that the shoot and root length of the seedlings, vigour index and dry weight of seedlings recorded maximum values in the fourth picking with lower values in the previous and subsequent pickings in pure seed crop of bhindi.

Asokmehta and Ramakrishnan (1986) found no significant variation in the root length of chilli seedlings with fruit pickings in the two varieties (Co1 and Co2) tried while the shoot length of first three pickings were on par in Co-1 the highest being in third picking. In Co-2 also the third picking showed the highest shoot length, this being on par with that of sixth pricking. Vigour index in Co-1 was highest in second picking which was on par with that of other pricking. The seeds of Co-2 showed the highest vigour index in the third picking and the lowest in the first picking.

In bhindi there was no significant difference in the seedling root and shoot length and vigour index when the early formed fruits upto four green fruits were harvested for vegetable compared to no vegetable harvesting (Natraj *et al.*, 1992).

Sheeba (1995) observed that vegetable harvests had significant effect on seedling root length, shoot length and vigour index. These parameters were maximum in two vegetable harvest which was significantly superior to four vegetable harvests.

2.2 Effect of growth regulators

The role of plant growth regulators in various physiological and biochemical processes in plants is well known. Growth regulators are found to have a profound influence on increasing the fruit and seed yield and also the seed quality parameters on various crops. The available literature on this aspect is reviewed here.

2.2.1 Effect on growth and fruit yield

In cucumber foliar sprays with ethephon at 150-500 mg l^{-1} has been reported to give highest fruit yield (Bhandari *et al.*, 1974). Higher fruit yield with foliar sprays of ethephon at 25 mg l^{-1} is reported in summer squash (Singh *et al.*, 1975) ; pumpkin (Shanmughavelu *et al.*, 1973 ; Das and Swain, 1977; Arora and Partap, 1988) and in ridge gourd (Arora *et al.*, 1987). Sinha (1975) reported highest fruit yields in chilli by foliar sprays of GA at 50 mg l^{-1} at fruit setting. Similar results were also observed in chilli by NAA at 10 mg l^{-1} twice (at flowering and 5 weeks later) (More *et al.*, 1975 ; Chandra *et al.*, 1976 ; Pandita *et al.*, 1980 ; Patil *et al.*, 1985 ; Yamgar *et al.*, 1986).

Chhonkar *et al.* (1977) reported increase in fruit yield with foliar spray of ethephon at 200 mg l^{-1} and CCC at 250 mg l^{-1} in okra. In sweet pepper (*Capsicum annuum*) highest fruit yields were obtained from plants treated with ethephon at 600 ppm three times at early growth stages of the plant (Mahmoud, 1982). Dubey (1983) reported a three fold increase in yield over the control in sponge gourd when ethephon was applied twice at a concentration of 250 mg l^{-1} at two leaf stage and again at three to four leaf stages of growth. Arora *et al.* (1985) observed that Maleic hydrazide at 150 mg l^{-1} applied to sponge gourd and 250 mg l^{-1} to summer squash and GA_3 at 25 mg l^{-1} applied to water melon are effective in stimulating stem elongation, increasing the number of branches per plant and producing highest fruit yields.

Ethephon 150 ppm at two true leaf stage recorded the highest number of fruits per plant and yield in cucumber (El-Ghamainy *et al.*, 1985). Srinivas *et al.* (1986) reported that foliar sprays of triacontanol @ 2 mg l^{-1} 30 days after transplanting and again at bloom were effective in enhancing fruit yield. Kumar and Peter (1986) reported that in *Cucumis* sp. ethephon at 100, 200 and 300 ppm cause significant reduction in length of main vine, but the treatment significantly increased the fruit yield per plant. Ethephon had no significant effect on fruit length, weight and volume. Ethrel at 100 ppm at two and four leaf stages is the best treatment in increasing the number of fruits and resulted in smaller size of fruits (Verma *et al.*, 1987). In pumpkin Arora *et al.* (1989) reported that ethephon at 250 and 100 ppm significantly increased the number of fruits per vine and yield per hectare because of a reduction in sex ratio resulting in more fruits per plant.

Verma *et al.* (1990) reported that in pumpkin ethrel treatments at two and four leaf stages reduced the fruit girth and diameter. In tomato highest yield were obtained by foliar application of NAA at 20 ppm (Phookan *et al.*, 1991). Application of maleic hydrazide at 200 ppm had significantly increased the fruit weight, number of fruits per plant, yield per plant and yield per hectare in bittergourd (Suresh and Pappiah, 1991). Devadas and Ramadas (1994) reported that in bittergourd a significant yield increase has been reported with ethephon 100 ppm sprayed at four leaf and vining stages of plant growth. The same authors have also reported significantly higher and maximum fruit yield 120 per cent more than untreated control by the application of triacontanol five ppm. In pumpkin, Das and Das (1996) found that ethephon applied at 200 ppm shortened the vine length, produces the maximum number of branches, more fruits per vine and the highest average yield of fruits in pumpkin.

2.2.2 Effect on seed yield and quality

Ethephon at 250 mg l^{-1} sprayed at flowering and full bloom stages increased the seed yield in cauliflower variety snowball - 16 (Sinha, 1974). Singh *et al.* (1976) reported that in cauliflower significantly higher seed yields were obtained by the application of 150 ppm ethrel at the time of initiation of primary floral stalks. Other parameters like number of seeds per siliqua, seed yield per plant and germination percentage were also highest for this treatment.

Gibberellic acid at 50-250 mg l^{-1} improved seed yield but delayed maturity in cauliflower (Mangal *et al.*, 1980). Mahmoud (1982) reported highest seed yields from sweet pepper plants treated with 600 ppm ethephon in early growth stages. Indole acetic acid and Gibberellic acid (10 mg l^{-1}) gave the best seed yields in pea when compared to the untreated control (Dawale, 1983). In chillies, Hariharan and Unnikrishnan (1983) reported enhanced seed yield and seed size by presowing seed treatment with NAA at 30, 35 and 70 mg l^{-1}.

Edelstein *et al.* (1985) found that application of 500-600 ppm of ethephon at 2, 4 and 6 leaf stages and again about a month later at fruit set resulted in significantly higher seed yield. In cucumber significantly higher seed yield are obtained by the application of 250 ppm of ethephon but the germination percentage of seed was unaffected due to the spraying of ethephon (El-Beheidi *et al.*, 1987). Sitaram *et al.* (1989) reported that foliar sprays of ethephon 200 ppm at 1-2 true leaf stage resulted in increased fruit and seed yield. This treatment gave 43 per cent increase in fruit yield and 58 per cent improvement in seed weight per fruit over the untreated control. But the germination potential of seeds were not influenced by growth regulator. Arora *et al.* (1989) observed increased seed weight per fruit in pumpkin due to the application of GA_3 at 25 ppm. In sunflower, Uppar and Kulkarni (1989) reported significantly higher seed yield per hectare, seed recovery percentage, seed yield per plant and 1000 seed weight by the foliar application of TIBA at a concentration of 250 ppm. But application of growth regulator does not influence the germination percentage and vigour index of seedling.

In tomato significantly higher fruit and seed yields were obtained by the application of NAA at 20 ppm at flowering stage (Phookan *et al.*, 1991). Singh *et al.* (1991) found that foliar application of Mixtalol at the rate of 30 ml in 10 l of water causes significant increase in seed yield and quality parameters. Devadas and Ramadas (1994) could observe that in bittergourd foliar application of triacontanol five ppm resulted in higher seed number per fruit. Kene *et al.* (1995) reported that in sunflower highest seed yield, 100 seed weight, plant height and number of branches are obtained by pre-soaking the seeds with GA at 20 ppm. In safflower foliar application of GA at 15 ppm results in significantly higher and maximum LAI, plant height and number of branches, but seed weight and seed yield per hectare were significantly higher by GA at 15 and 30 ppm and by Indole butyric acid 30 ppm at flowering stage (Kene *et al.*, 1995 a). Deotale *et al.* (1996) reported that TIBA increased leaf area index, dry matter and seed yield per hectare with concentrations upto 600 ppm at 60, 80 and 100 DAS in safflower. In bittergourd NAA at 50 ppm gave the highest number of seeds per fruit which was significantly higher than other treatments (Gedam *et al.*, 1996).

2.3 Studies on physiological maturity of seeds

The stage of seed maturity at harvest is an important factor which affect seed quality and its subsequent performance. Seed maturity has critical implications for seed quality in terms of their germinability and vigour. Seeds attain maximum quality at their physiological maturity (Helmer *et al.*, 1962) and it is attained at a particular stage of development of seed on the plant. Information available on the fruit and seed maturity studies in various crops are reviewed here.

2.3.1 Seed characters

Odland (1937) revealed that if the fruits of cucurbits were allowed to remain on the vine until over ripe, the seed will germinate promptly, but if fruits were picked at ripe stage, the germination could be delayed for several weeks. Seatson (1938) studied the relation of number of seeds to fruit size and reported that weight of fruits and number of good seeds had correlated significantly.

Seed quality is maximum at the physiological maturity stage and depends on environmental conditions. Prolonged field exposure after the stage of maturity would result in losses in germinability, longevity and vigour of seedling produced (Mc Alister, 1943 and Garris and Hoffmann, 1946). Increase in fresh weight during the development of fertilized ovules into seeds was noticed by Young (1949) in squash. The term physiological maturity has been most frequently used to describe the point where the seed reaches its maximum dry seed weight (Shaw and Loomis, 1950).

Harrington (1959) studied the effect of days from anthesis to harvest in germination of muskmelon seeds. The 100 seed weight increased upto 37 d.a.a. and beyond that there is slight decrease in 100 seed weight. The number of seeds per fruit did not change with time from anthesis. The stage of maturity of fruit had an extreme effect on germination of seeds. The seeds harvested at 37, 42 and 47 d.a.a. and immediately subjected to germination showed no much differences in germination between 37 and 47 d.a.a. but a slight difference had developed four months after harvest and it persisted nine months after harvest.

According to Chauhan and Bhandari (1971), the age of the fruits significantly affected germination in bhindi. There observed difference in germination among seeds obtained at varying period of maturity from apical, middle and basal portions of fruits in bhindi. Seeds collected 27 days after flower opening recorded 89.2 per cent and while those harvested at 30 days recorded a lesser germination of 85.8 per cent. Patapova (1972) reported that the dry weight of cucumber seed increased with increase in maturity. The quality of the seed is basically dependent on its filling and on the metabolic and synthetic efficiency during seed development and maturation. Seed development and maturation refers to the morphological, physiological and functional changes that occur from the time of fertilization until the mature seeds are ready for harvest (Delouche, 1973). Abdul - Baki and Baker (1973) used the fresh weight of seed for differentiating seed development and seed maturation. According to them, the seed development is a period between fertilization and maximum fresh weight of seeds and maturation begins at the end of seed development and continues up to harvest.

Shanmugaraj (1978) reported that in lablab (*Lablab purpureus* (L.) sweat), seeds attained the maximum dry weight and physiological maturity on 27 d.a.a. Studies conducted at the Tamil Nadu Agricultural University have shown that physiological maturity of seed was obtained at 60 d.a.a. in ribbed gourd and 27 d.a.a. in bittergourd (Varatharaj, 1979). Chandrasekaran (1979) found that in bottlegourd, seeds attain maximum dry weight and maximum physiological maturity at 65 d.a.a. Krishnaprasad (1980) reported that in ashgourd, seeds became germinable at 50 d.a.a. and seeds reached maximum physiological maturity and vigour potential at 80 d.a.a.

Chin (1981) observed that long bean (*Vigna sesquipedalis*) seeds which are subjected to storage, the germination percentage was lower in immature seeds and highest for fully matured seeds. Metha (1983) reported that in chilli, physiological maturity of seed was attained at 48 d.a.a and seeds from fruits harvested before attaining physiological maturity after storage for 12 months possessed relatively low germination and field emergence potential and produced seedlings with poor growth and vigour. In watermelon, physiological seed maturation occurred at 55 d.a.a. and best quality seeds were obtained from fruits harvested at 35 and 45 d.a.a. and stored for four days (Alvarenga *et al.*, 1984).

Hedayat (1987) reported that watermelon seeds attained maximum 100 seed weight and germination per cent at 42 d.a.a. Kanwar and Saimbhi (1987) reported that in okra, seed weight per pod and germination percentage were maximum from pods harvested at 35 d.a.a. Further delay in harvesting the pods increased the number of damaged seeds and reduced the seed weight and germination per cent. In muskmelon, seed quality was the best when harvested at 'full slip' stage (Harisingh *et al.*, 1988). Nerson and Paris (1988) observed seeds from immature fruits of cucumber (26 and 33 days past anthesis) had low germination and storability when compared to mature fruits (40 and 54 days past anthesis). The seeds harvested at the ripe fruit stage showed high germination capacity and seedling vigour in chilli (Doijode, 1988).

Jayabharathi *et al.* (1990) reported that brinjal fruits should be harvested at full yellow stage for maximum seed yield, germination and vigour parameters. Harvesting at this optimum stage of maturity not only minimises the loss in viability and vigour of seeds but also prevents the seeds from damages due to adverse environmental conditions as well as from insects and fungal damages. Choudhari *et al.* (1992) found that in tomato, percentage germination, 100 seed weight, seedling height and vigour index increased with fruit maturity and were highest for seeds extracted from fruits at the red ripe stage. In groundnut the mean seed weight, germination percent and vigour index were highest when the seeds were collected 60 d.a.a. (Jayaraj and Karivaratharaju, 1992). In peas, Jayaraj and Karivaratharaju (1992a) reported that seeds attain physiological maturity on 50^{th} day after anthesis where the germination, dry matter production and vigour index values were maximum. Katiyar and Dubey (1992) reported superior values for root and shoot length, total seedling growth and vigour index with seeds stored from harvest at physiological maturity in chickpea. In chilli Dhanelappagol *et al.* (1994) observed that seeds from the fruits harvested at full red stage recorded highest mean germination, field emergence, seedling root and shoot length and vigour index. In okra cv. 'Akkoy', maximum seed quality was recorded at 52 d.a.a. At this stage seeds were mature with a moisture of 12 per cent. Delaying harvest to 59 d.a.a. resulted in seed loss due to shattering in okra (Demir, 1995). Naik *et al.* (1996) found that in *Capsicum* the seed yield per fruit, 1000 seed weight, germination percent, root and shoot lengths and seedling dry weight were highest for seeds collected from fully mature shrinking fruits. Indira and Dharmalingam (1996) reported that in fenugreek seeds attain harvestable maturity at 45 d.a.a. which is evident from highest 100 seed weight, germination percent, seedling root length, shoot length, dry matter production and seedling vigour. In fodder cowpea the maximum germination percent and seed weight occurred at 17 d.a.a. which coincides with the physiological maturity (Rakeshseth *et al.*, 1999).

2.4 Storage of intact fruits after harvest

Post harvest storage of cucurbit fruits for seed purpose is an age-old practice followed by farmers. The effect of such storage on seed quality parameters are reviewed in this chapter.

Cochran (1943) showed that seeds of *Capsicum fruitescens* extracted from 30 days old fruits gave approximately five per cent germination immediately after harvest but the fruits picked at the same stage which were kept for a further 30 days before seed extraction gave a seedling emergence of 95 per cent. Young (1949) recorded that in butternut squash the 100 seed weight increased during fruit storage both in mature and immature fruits. The seeds removed from mature squash at the start of the storage had an average germination of 90.8 per cent whereas four months after storage it increased to 98.4 per cent; the germination of seeds of immature squash which was 19 per cent in the beginning of storage had increased to a maximum of 67.2 per cent after four months of storage of fruit. It was concluded that to obtain seeds with good germination only very mature butternut squash fruits should be harvested and stored for four months. Petrov and Dojkov (1970) reported that in brinjal storage of immature fruits for 3, 5 and 7 days increased the percentage germination of seeds but did not affect the absolute seed weight.

Quagliotti *et al.* (1981) reported that in chilli post-harvest ripening of the seed is essential and it increased the percentage of fruits containing viable seeds. Araujo *et al.* (1982) reported that seed germination in cucurbits was increased with increasing fruit age and storage length. Buriev (1987) reported that in cucumber, after ripening improved seed quality and best quality seeds were obtained from 40 day old fruits, after ripened for 10 or 15 days. In *Cucurbita pepo* fruits stored in airy loft after harvest for two weeks produced best results in terms of germination (Nagy, 1987).

Krishnaswamy (1991) reported that in bittergourd, seeds continue to mature in fruits which were harvested before ripening and stored under ambient conditions. Harvesting of fruits three days before full ripening and storing under ambient conditions for four days before extraction produced high quality seeds.

Experiments were conducted in chilli to investigate whether seed viability can be prolonged by storing seeds in fruits itself. Four varieties of chilli viz., Pusa Sadabahar, LGP, Pant C-1 and G-3 were used for the study. During initial periods of ageing, extracted seeds showed a higher reduction in mean germination, compared to seeds stored with in fruits. However at later periods of ageing, differences in germination reduction were negligible. Similar trend was observed in three of the varieties except in variety G-3, where storing seeds within fruits had some advantage in prolonging viability and vigour (Vasanthakumar and Singhal, 1994). Robinson and Decker-Walters (1997) reported that cucurbit seed will continue to develop even after the fruit is removed from the vine. Eventhough the fruits are picked at immature stage, best quality seeds are obtained when the fruits are stored intact for one or two months before extracting the seeds.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was conducted at College of Agriculture, Vellayani during the period from 5-11-99 to 05-02-2000 for assessing the effect of periodical harvest and growth regulator on seed yield, quality and vigour of cucumber seed and for standardising the physiological stage of maturity of the seed. Two experiments were conducted with the following objectives.

I. To study the effect of harvest and growth regulator on seed yield and quality.

II. Standardisation of physiological maturity stage.

The details of the materials used and methods adopted are presented in this chapter.

3.1 Materials

3.1.1 Experimental site

The experiment was conducted at the Instructional Farm attached to College of Agriculture, Vellayani situated at 8.5^0 N latitude, 76.9^0 E longitude and at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental site was lateritic red loam belonging to the order oxisol and textural class sandy clay loam. The physicochemical properties of the experimental site are presented in table I.

Table 1 Physico-chemical properties of soil

A. Physical composition

Sl. No.	Parameter	Content in soil(per cent)	Method used
1.	Course sand	36.35	Bouyoucos hydrometer method
2.	Fine sand	15.00	(Bouyoucos, 1962)
3.	Silt	17.50	
4.	Clay	30.00	

B. Chemical composition

Sl. No.	Parameter	Content	Rating	Method used
1.	Available N	486.06 kg ha^{-1}	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5	66.00 kg ha^{-1}	High	Bray colorimetric method 1 (Jackson, 1973)
3.	Available K_2O	28.00 kg ha^{-1}	Low	Ammonium acetate method (Jackson, 1973)
4.	pH	4.80	Acidic	pH meter

3.1.3 Cropping history of the field

The experimental area was previously cropped with a bulk crop of vegetable prior to the layout of the experiment.

3.1.4 Season

The experiment was conducted during November to February of 1999-2000.

3.1.5 Weather conditions

The weekly averages of temperature, relative humidity and the weekly total of rainfall during the cropping period collected from the meteorological observatory at the College of Agriculture are presented in Appendix - I and Fig. 1.

3.1.6 Cultivar used

The cultivar of cucumber used for the this study was Swarnapoorna. This variety was evolved at Central Horticultural Experiment Station, Ranchi.

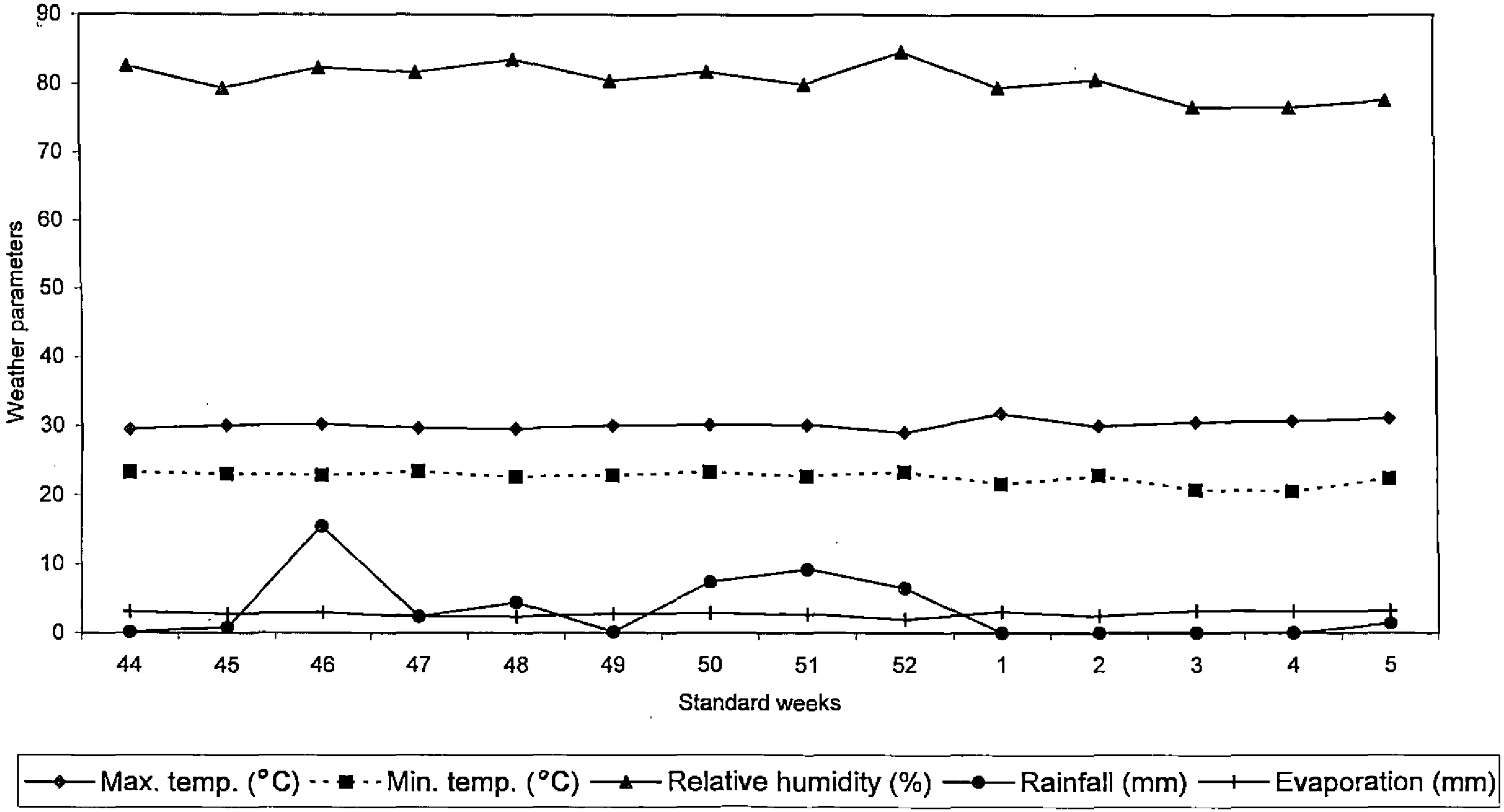
3.1.7 Source of seed material

The seeds of variety Swarnapoorna obtained from Central Horticultural Experiment Station, Ranchi was used for the experiment.

3.1.8 Growth regulator

Ethephon (38 per cent) which is chemically 2 chloro ethyl phosphonic acid was used for the experiment.

Fig. 1 Weather parameters during the cropping period (November 1999 to February 2000)



3.1.9 Manures and fertilizers

FYM (0.4 per cent N; 0.2 per cent P; 0.3 per cent K) was used as the organic manure. Urea (46 per cent N), Mussorie rock phosphate (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as the source of inorganic fertilizers.

3.2 Methods

3.2.1 Design and lay out

3.2.1.1 Experiment - I

The field experiment was laid out in strip plot design. The lay out of the experiment is given in Fig. 2. The experimental details are given below.

3.2.1.1.1 Treatments

The treatments consisted of combinations of varying number of vegetable harvests and different concentrations of growth regulators.

A. Vegetable harvests

h_1 : No vegetable harvest (entire crop left for seed collection)

h_2 : One Vegetable harvest and the rest left for seed collection

h_3 : Two Vegetable harvest and the rest left for seed collection

B. Levels of Ethephon (ppm)

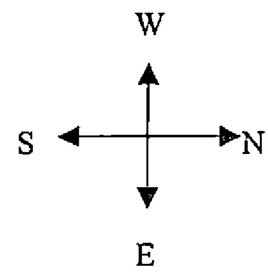
g_1 : 0 ppm

g_2 : 100 ppm

g_3 : 200 ppm

g_4 : 300 ppm

Fig. 2 Layout of Experiment I



$h_2 g_1$	$h_2 g_2$	$h_2 g_4$	$h_2 g_3$
$h_1 g_1$	$h_1 g_2$	$h_1 g_4$	$h_1 g_3$
$h_3 g_1$	$h_3 g_2$	$h_3 g_4$	$h_3 g_3$

Replication 1

$h_3 g_2$	$h_3 g_4$	$h_3 g_3$	$h_3 g_1$
$h_2 g_2$	$h_2 g_4$	$h_2 g_3$	$h_2 g_1$
$h_1 g_2$	$h_1 g_4$	$h_1 g_3$	$h_1 g_1$

Replication 2

$h_3 g_3$	$h_3 g_2$	$h_3 g_1$	$h_3 g_4$
$h_1 g_3$	$h_1 g_2$	$h_1 g_1$	$h_1 g_4$
$h_2 g_3$	$h_2 g_2$	$h_2 g_1$	$h_2 g_4$

Replication 3

3.2.1.1.2 Treatment combinations

T_1 : $h_1 g_1$	T_7 : $h_2 g_3$
T_2 : $h_1 g_2$	T_8 : $h_2 g_4$
T_3 : $h_1 g_3$	T_9 : $h_3 g_1$
T_4 : $h_1 g_4$	T_{10} : $h_3 g_2$
T_5 : $h_2 g_1$	T_{11} : $h_3 g_3$
T_6 : $h_2 g_2$	T_{12} : $h_3 g_4$

Number of treatment combinations = 12

Number of replications = 3

Total number of plots = 36

Gross plot size = 8 m x 4.5 m

Net plot size = 6 m x 3 m

Spacing = 2 m x 1.5 m

3.2.1.2 Experiment - II

The experiment was laid out as a factorial experiment in Randomised Block Design. The layout of the experiment is shown in Fig. 3. The experimental details are given below.

3.2.1.2.1 Treatments

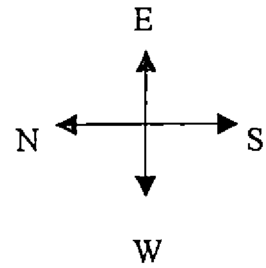
A. Seed harvesting stage

s_1 : Harvesting at 15 days after flowering

s_2 : Harvesting at 30 days after flowering

s_3 : Harvesting at 45 days after flowering

Fig. 3 Layout of Experiment II



T_1	T_4	T_9	T_6	T_{10}	T_4
T_7	T_8	T_5	T_{12}	T_1	T_2
T_3	T_{10}	T_8	T_7	T_{11}	T_5
T_6	T_2	T_{10}	T_3	T_6	T_8
T_{12}	T_{11}	T_1	T_2	T_{12}	T_3
T_9	T_5	T_{11}	T_4	T_7	T_9
← R_1 →		← R_2 →		← R_3 →	

B. Extraction time

r_1 : Extraction of seed on the same day of harvest

r_2 : Extraction three days after harvest

r_3 : Extraction six days after harvest

r_4 : Extraction nine days after harvest

3.2.1.2.2 Treatment combinations

T_1 : $s_1 r_1$	T_7 : $s_2 r_3$
T_2 : $s_1 r_2$	T_8 : $s_2 r_4$
T_3 : $s_1 r_3$	T_9 : $s_3 r_1$
T_4 : $s_1 r_4$	T_{10} : $s_3 r_2$
T_5 : $s_2 r_1$	T_{11} : $s_3 r_3$
T_6 : $s_2 r_2$	T_{12} : $s_3 r_4$

Number of replications	= 3
Total number of plots	= 36
Spacing	= 2 m x 1.5 m
Gross plot size	= 8 m x 4.5 m
Net plot size	= 6 m x 3 m

3.2.2 Field culture

3.2.2.1 Land preparation

The experimental area was first cleared of weeds and stubbles. The field was laid out into strips and plots as per the design. Individual plots were dug well, levelled and pits of 60 cm diameter and 30-45 cm depth were taken at 2 m x 1.5 m spacing. Each pit was filled with a mixture of powdered well decomposed FYM and top soil before sowing.

3.2.2.2 Application of manures and fertilizers

The manures and fertilizers were applied as per package of practice recommendations of KAU (KAU, 1996) and the recommended management practices were adopted uniformly to all the treatments.

3.2.2.3 Seeds and sowing

Good, bold seeds were selected and sown at the rate of six seeds per pit.

Two weeks after sowing, the excess plants were thinned out retaining four healthy seedlings in each pit.

3.2.2.4 After cultivation

The crop was irrigated and weeded as and when required. Top dressings with nitrogen were done two times at vining stage and at the time of flowering.

3.2.2.5 Plant protection

As a prophylactic measure against red pumpkin beetle and fruit flies, soil application of Furadan 3G at the time of sowing was adopted. Drenching with Bavistin was done at seedling stage to control damping off. Repeated spraying of Rogor against red pumpkin beetle and Malathion against fruit flies were done for getting satisfactory fruit and seed yield.

3.2.2.6 Application of growth regulator

Ethephon in different concentrations (0, 100, 200 and 300 ppm) as per treatment was sprayed on the foliage of seedlings at two leaf stage (15 DAS).

3.2.2.7 Harvesting

Fruits were harvested as vegetable at five days interval as per the treatments from 45 DAS and a total of three vegetable harvests were done for the first experiment. The green fruits were harvested at vegetable maturity stage as judged by visual observations. The ripe fruits were harvested when the fruit colour turn yellow.

For second experiment, fruits were harvested according to the treatment at 15, 30 and 45 days after flowering and seed extraction as per treatment was done on the same day, three days, six days and nine days after harvest.

3.2.3 Observations recorded

Four plants per plot were selected at random for taking observations and the following biometric and yield attributes were recorded from these plants.

3.2.3.1 Biometric observations

3.2.3.1.1 Length of main vine

The length of vine was recorded on the four observational plants at three stages viz., 30 DAS, 60 DAS and at final harvest. The length of the longest vine was measured from base to the tip of the vine and the mean length per vine worked out.

3.2.3.1.2 Number of branches

Number of branches from all the observational plants were counted and mean worked out.

3.2.3.1.3 Leaf area index (LAI)

LAI was worked out at three stages viz., 30 DAS, 60 DAS and at final harvest. Area of three leaves per plant was worked out from one sample plant at each stage of observation. The area of three leaves per plant representing the three parts of the plant (base, middle and tip) were recorded using LI-3100 leaf area meter and LAI was worked out using the formula suggested by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

3.2.3.2 Yield observations

3.2.3.2.1 Number of green fruits per plant

From the total number of fruits harvested as vegetable from the observational plants, the per plant fruit number was calculated.

3.2.3.2.2 Length of the fruit

The length of the fruits harvested from the observational plants in each harvest was measured, the mean worked out and expressed in cms.

3.2.3.2.3 Girth of the fruit

The same fruits used for measuring the length were used for finding the girth. Measurement was effected by winding a thread around middle part of each fruit. The mean values were worked out and expressed in cms.

3.2.3.2.4 Weight of green fruits per plant

The weight of green fruits obtained from the observational plants were recorded at each harvest. The total weight of the fruits plant^{-1} from the vegetable harvests was worked out and the mean calculated.

3.2.3.2.5 Green fruit yield

The total weight of green fruits from the net plot area was calculated and recorded as kg ha^{-1}.

3.2.3.2.6 Weight of mature fruits per pant

The weight of mature fruits obtained from the observational plants were recorded at each harvest and the total weight of fruits from the harvests was calculated and expressed as mature fruit yield plant^{-1}.

3.2.3.2.7 Mature fruit yield

The total weight of mature fruits obtained from the net plot area was recorded and converted into kg ha^{-1}.

3.2.3.2.8 Total number of fruits harvested plant^{-1}

The total number of fruits harvested from the observational plants were calculated at the end of the cropping season and the mean recorded.

3.2.3.2.9 Shelf life of fruit

The fruits collected from different treatments were kept under ambient conditions and the days upto which quality was maintained without deterioration i.e., change in colour, shrinkage, microbial growth etc., was recorded.

3.2.3.3 Seed characters

3.2.3.3.1 Number of seeds per fruit

Seeds from the fruits of observational plants were collected, the number of seeds were counted and seed number per fruit was calculated.

3.2.3.3.2 Weight of seed per fruit

The fruits used to record the number of seeds fruit^{-1} were used for noting the weight of seeds fruit^{-1}. The weight of seed from each fruit was recorded and the mean worked out.

3.2.3.3.3 Fruit to seed ratio

The fruit to seed ratio was worked out at each harvest by dividing the weight of all fruits from observational plants with the weight of seeds of the respective fruits and the mean worked out.

3.2.3.3.4 1000 seed weight

100 seeds were counted at random from the observational plants and weighed. These values were multiplied by 10 to obtain the 1000 seed weight and expressed in gram.

3.2.3.3.5 Seed yield per plant

The weight of seeds from the observational plants were recorded at each harvest and the mean worked out and expressed as g plant^{-1}.

3.2.3.3.6 Seed yield per hectare

The total weight of seeds from the net plot area was calculated at the end of the cropping season and the yield in kg ha^{-1} computed.

3.2.3.3.7 Germination percentage

Pure seed fraction of the different treatments were tested for germination. Forty seeds per treatment were sown on whatman paper in petridishes of 9 cm size. The paper was kept moist until the final count was taken on the 10th day. The number of seeds germinated were counted on the last day and the percentage worked out.

3.2.3.3.8 Seedling shoot length

Ten seeds selected at random from each treatment were sown in germination trays with sand as the medium. The seeds were allowed to sprout with daily watering and after ten days they were uprooted and the length of shoots were measured from the collar region to the base of terminal bud, the mean worked out and expressed in cms.

3.2.3.3.9 Seedling root length

The seedlings used for measuring shoot length were used for this purpose also. The root length was measured from the collar region to the root tip. The average was worked out and recorded in cms.

3.2.3.3.10 Vigour index of seedling

Seedling vigour index (VI) was calculated by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed as a number.

VI = Germination per cent x (Root length + Shoot length)

The data recorded on observations 3.2.3.3.7, 3.2.3.3.8 and 3.2.3.3.9 were used for the purpose. The mean was calculated and expressed as seedling vigour.

3.2.3.3.11 Seedling dry weight

The seedlings used to measure root and shoot length were dried at 105^0C in air oven for 17 ± 1 hours and the dry weight was noted. The mean dry weight was worked out and expressed as mg per seedling.

3.2.3.3.12 Speed of germination

From the samples kept for determination of root and shoot length, the number of seedlings emerged was recorded daily until the final count day (10 days after sowing). The speed of germination was then calculated by adding the quotients of the daily count divided by the number of days of germination (Agrawal, 1980).

3.2.3.3.13 Seed viability

Seed viability test was done using Topographical Tetrazolium chloride method. 10 seeds of each treatment were pre-conditioned by soaking in water for 12 h, dissected longitudinally through the embryo and then kept in 0.1 per cent colourless tetrazolium chloride solution. Living tissues attained a red stain in tetrazolium solution indicating the viability of seeds.

3.2.4 Economics of cultivation

The economics of cultivation was worked out based on the various input costs.

$$\text{Net income (Rs ha}^{-1}\text{)} = \text{Gross income - Cost of cultivation}$$

$$\text{Benefit : Cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.2.5 Statistical analysis

The data generated from the experiment were subjected to Analysis of Variance (ANOVA) technique as applied to strip plot design (Cochran and Cox, 1965) for experiment I and ANOVA technique as applied to RBD for experiment II. When effects were found to be significant, critical differences were calculated for effecting comparison among treatments.

RESULTS

4. RESULT

The present investigation entitled "Effect of harvesting and growth regulator on seed yield, quality and vigour in cucumber" was conducted to study the effect of harvesting and growth regulator on seed yield and quality. The study also aimed at standardizing the physiological stage of maturity of seed. This study was conducted as two separate experiments. The results obtained are presented under the following sections.

4.1 Experiment I

Effect of number of harvest and growth regulator on seed yield and quality in cucumber.

4.1.1 Growth characters

The effect of number of harvest, growth regulator and their interaction on various growth characters are presented in table 2.

4.1.1.1 Length of vine

Vine length was observed to be higher in plants with one or two harvests. Vine length was maximum (190.83 cm) when two vegetable harvests (h_3) were done which was significantly superior to the vine length of plants left without vegetable harvest (h_1, 156.60 cm) but was on par with one vegetable harvest (h_2).

Table 2 Average main effect of harvest and growth regulator on growth characters

Treatments	Length of vine (cm)	Number of branches	LAI
h_1	156.60	2.95	0.93
h_2	189.29	3.68	1.11
h_3	190.83	3.80	1.28
$F_{2,4}$	90.82**	77.50**	29.03**
SE	5.32	0.07	0.03
CD	7.69	0.21	0.13
g_1	195.15	3.25	1.06
g_2	175.39	3.48	1.09
g_3	173.03	3.57	1.11
g_4	172.05	3.60	1.16
$F_{3,6}$	31.18**	1.16^{ns}	13.07**
SE	4.37	0.06	0.029
CD	6.77	-	0.04

** Significant at 1 per cent
ns - Not significant

Growth regulator caused significant reduction in vine length of plants. Longest vine (195.15 cm) was produced by g_1 (zero ppm) which was significantly superior to g_2 (100 ppm), g_3 (200 ppm) and g_4 (300 ppm) with the shortest (172.05 cm) in g_4.

The interaction H x G was not significant.

4.1.1.2 Number of branches per plant

Number of branches per plant also showed a significant increase in plants with vegetable harvest following the same trend as that of vine length with the highest number (3.80) being in h_3 and which was on par with h_2 and the lowest (2.95) in h_1.

Growth regulator had no significant influence on the number of branches per plant.

H x G interaction was also not significant.

4.1.1.3 Leaf Area Index

LAI recorded the highest value (1.28) in plants in which two vegetable harvests were done (h_3) which was significantly superior to h_2 and h_1.

Application of growth regulator also caused a significant increase in LAI. LAI was maximum (1.16) for g_4 (300 Ppm) which was significantly superior to g_3, g_2 and g_1 but g_1 and g_2 were on par.

H x G interaction was not significant.

4.1.2 Yield and yield attributes

The results on fruit yield and yield attributes are presented in Tables 3 and 4.

4.1.2.1 Number of green fruits per plant

Number of vegetable harvests significantly influenced the number of green fruits. The plants in which green fruit picking was done twice (h_3) recorded highest number of fruits (17.50) compared to those harvested once (10.58). h_3 recorded 65 percent increase in number of green fruits per plant over h_2.

The effect of growth regulator was also significant. The number of green fruits was only 6.5 in g_1 (zero ppm) which was doubled by g_2 (100 ppm) and increased to a maximum of 18.83 at g_3 (200 ppm) recording 185 percent increase over g_1. However a further increase in the concentration of growth regulator to 300 ppm (g_4) did not show this positive effect.

H x G interaction was not significant.

4.1.2.2 Weight of green fruits per plant

Weight of green fruits per plant was maximum for two vegetable harvests h_3 (1853.65g) which was significantly superior to one vegetable harvest h_2 (902.49g).

Weight of green fruits per plant was maximum (1876.72g) for g_3 (200 ppm) which was significantly superior to g_2 and g_1 but on par with g_4.

Significant interaction effect of harvest and growth regulator had shown when one vegetable harvest was done (h_2) the fruit weight was 234.50 g for g_1 (zero ppm) which was increased to 749.64 g for g_2 (100 ppm) and to 1310.54 g for g_3 (200 ppm) contributing to a gain of 219 and 458 percent respectively over g_1. However, a further increase in concentration of growth regulator to 300 ppm (g_4) did not cause any appreciable increase. When two vegetable harvests were done the fruit weight was 828.62 g for g_1 which was increased to 1827.28 g for g_2 and 2442.89 g for g_3 which showed an increase of 120 and 194 percent respectively over g_1. Here also g_4 did not recorded an enhanced fruit weight. Among the combinations h_3 g_3 recorded the maximum weight of green fruits per plant which was on par with h_3 g_4.

4.1.2.3 Green fruit yield

Green fruit yield was the highest for h_3 (8552.29 kg ha^{-1}) which was significantly superior to h_2 (3405.82 kg ha^{-1})

Among the levels of growth regulator g_3 recorded the highest green fruit yield (7197.93 kg ha^{-1}) which was significantly superior to g_2 and g_1 but on par with g_4. g_3 recorded an 81.7 percent increase over g_1.

The results on interaction had shown that when one vegetable harvest was done (h_2) the fruit yield at g_1 (zero ppm) was only 1640.88 kg ha^{-1} which was increased to 2532.30 kg by 100 ppm ethephon (g_2) and to 4723.30 kg ha^{-1} at 200 ppm (g_3) recording an increase of 54 and 187 percent respectively over g_1. At h_3 level, g_1 recorded a yield of 6280.80 kg ha^{-1} and was increased to 8790.11 kg ha^{-1} by g_2 and to 9672.56 kg ha^{-1} by g_3 recording an increase of 40 and 54 percent respectively over g_1. However further increase in the concentration of growth regulator to 300 ppm (g_4) decreased the green fruit yield as compared to g_3. Here also the combination h_3 g_3 recorded maximum yield which was on par with h_3 g_4.

4.1.2.4 Weight of mature fruits per plant

The main effect of harvest and growth regulator on weight of mature fruits per plant was significant.

Weight of mature fruits per plant was maximum (2036.15g) in plants which were left as such without green fruit picking (h_1) and was significantly superior to those where one and two vegetable harvests were done (h_2 and h_3 respectively).

Among the levels of growth regulator, g_3 (200 ppm) recorded the highest weight of mature fruits per plant (1870.57 g) which was significantly superior to g_2 and g_1 but on par with g_4.

H x G interaction was not significant.

4.1.2.5 Mature fruit yield

Highest mature fruit yield of 6786.48 kg ha^{-1} was recorded when the plants were left as such without green fruit picking (h_1) which was significantly superior to h_2 and h_3 recording 34 percent increase over h_2 and 79 percent increase over h_3.

The effect of growth regulator showed that maximum mature fruit yield of 6234. 61 kg ha^{-1} was recorded at 200 ppm of ethephon (g_3) which was significantly superior to both g_2 and g_1 with 30 percent increase over g_2 and 90 percent over g_1 but on par with g_4.

H x G interaction was not significant.

4.1.2.6 Total number of fruits harvested per plant

Total number of fruits harvested per plant was highest (23.17) when vegetable picking was done twice (h_3) which was significantly superior to h_1 (11.67) and h_2, (16.92).

Number of fruits harvested per plant increased with increase in the concentration of growth regulator upto 200 ppm (g_3). Maximum number of fruits were obtained from g_3 (21.56) which was significantly superior to g_2 and g_1 but on par with g_4.

The interaction effect of harvest and growth regulator showed that when no vegetable harvest was done (h_1) the total number of fruits harvested was only 5.67 at zero ppm ethephon (g_1) which was increased to 10.00 at 100 ppm (g_2) and to 15.00 at 200 ppm (g_3) recording an increase of 76 and 165 percent respectively over g_1. The same trend was followed at h_2 and h_3 also. In both the cases an increase in concentration of ethephon above 200 ppm did not cause any significant increase in the fruit number.

Among the combinations h_3 g_3 recorded highest total number of fruits harvested per plant.

Table 3 Main effect of harvest and growth regulator on fruit yield and yield attributes

Treatment s	Number of green fruits plant^{-1}	Weight of green fruits plant^{-1} (g)	Green fruit yield (kg ha^{-1})	Weight of mature fruits plant^{-1} (g)	Mature fruit yield (kg ha^{-1})	Total number of fruits harvested per plant
h_1	-	-	-	2036.15	6786.48	11.67
h_2	10.58	902.49	3405.82	1513.45	5044.31	16.92
h_3	17.50	1853.65	8552.29	1138.19	3793.59	23.17
$F_{2,4}$	75.71*	955.67**	29916.66**	289.19**	73.97**	867.97**
SE	1.64	65.31	486.33	197.36	48.41	0.53
CD	3.42	132.39	128.03	104.12	1060.21	0.78
g_1	6.50	531.56	3960.84	983.65	3278.84	10.89
g_2	13.17	1288.46	5661.21	1440.49	4809.13	15.44
g_3	18.83	1876.72	7197.93	1870.57	6234.61	21.56
g_4	17.67	1815.55	7096.27	1865.67	6218.28	21.11
$F_{3,6}$	385.71**	233.38**	116.78**	78.47**	473.97**	103.75**
SE	0.83	100.41	97.74	51.42	380.41	0.99
CD	0.98	141.41	485.93	174.62	882.44	1.72

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

Table 4 Interaction effect of harvest and growth regulator on fruit yield and yield attributes

Treatments	Number of green fruits plant^{-1}	Weight of green fruits plant^{-1} (g)	Green fruit yield (kg ha^{-1})	Weight of mature fruits plant^{1} (g)	Mature fruit yield (kg ha^{1})	Total number of fruits harvested per plant
$h_1 g_1$				1506.67	5021.73	5.67
$h_1 g_2$				1900.17	6333.27	10.00
$h_1 g_3$				2317.08	7722.83	15.00
$h_1 g_4$				2420.67	8068.07	16.00
$h_2 g_1$	3.33	234.50	1640.88	826.92	2756.12	9.33
$h_2 g_2$	9.00	749.64	2532.30	1375.58	4584.81	14.33
$h_2 g_3$	14.67	1310.54	4723.30	1847.28	6156.98	21.67
$h_2 g_4$	15.33	1315.29	4726.81	2004.00	6679.33	22.33
$h_3 g_1$	9.67	828.62	6280.80	617.37	2057.69	17.67
$h_3 g_2$	17.33	1827.28	8790.11	1045.71	3485.39	22.00
$h_3 g_3$	23.00	2442.89	9672.56	1447.33	4823.95	28.00
$h_3 g_4$	20.00	2315.81	9465.72	1442.33	4807.29	25.00
$F_{6, 12}$	4.18^{ns}	15.95**	8.08**	1.53^{ns}	1.39^{ns}	5.51**
SE	1.12	25.37	240.41	370.16	661.42	0.91
CD	-	149.56	647.42	-	-	1.83

** Significant at 1 per cent
ns – Not significant

4.1.3 Fruit characters

The results are presented in Tables 5 and 6.

4.1.3.1 Length and girth of green fruits

Number of vegetable harvest had no significant effect on the length and girth of green fruits.

The effect of growth regulator was not significant on length of fruit but had significant influence on girth of fruits. Higher fruit girth (18.13 cm) was recorded in zero ppm ethephon (g_1) which was on par with g_3 (200 ppm) but significantly superior to g_2 and g_4 (300 ppm). g_2, g_3 and g_4 were also on par.

H x G interaction was not significant.

4.1.3.2 Shelf life of green fruits

Both the main effect of treatments and their interactions had no significant influence on shelf life of green fruits.

4.1.3.3 Length and girth of mature fruits

The effect of harvest, growth regulator and their interactions were not significant on length of mature fruits.

The significant interaction effect of harvest and growth regulator on girth of mature fruits was not important as the main effects were not significant.

Table 5 Main effect of harvest and growth regulator on fruit characters

Treatment s	Length of green fruits (cm)	Girth of green fruit (cm)	Shelf life of green fruit (days)	Length of mature fruit (cm)	Girth of mature fruit (cm)
h_1	-	-	-	22.63	23.53
h_2	16.69	16.66	2.00	23.33	23.48
h_3	15.06	15.24	2.08	22.00	23.52
$F_{2,4}$	1.22^{ns}	1.87^{ns}	0.08^{ns}	6.68^{ns}	0.004^{ns}
SE	0.81	0.79	0.002	0.91	1.21
g_1	17.51	18.13	2.00	21.84	23.69
g_2	14.60	14.47	2.00	23.51	23.54
g_3	16.40	16.41	1.83	23.15	23.89
g_4	15.00	14.79	2.33	20.78	22.95
$F_{3,6}$	1.29^{ns}	4.94*	0.45^{ns}	2.23^{ns}	0.51^{ns}
SE	0.76	1.51	0.004	0.87	1.07
CD	-	2.62	-	-	-

* Significant at 5 per cent
ns – Not significant

Table 6 Interaction effect of harvest and growth regulator on fruit characters

Treatment s	Length of green fruits (cm)	Girth of green fruit (cm)	Shelf life of green fruit (days)	Length of mature fruit (cm)	Girth of mature fruit (cm)
$h_1 g_1$				21.22	22.93
$h_1 g_2$				22.95	24.35
$h_1 g_3$				20.84	21.36
$h_1 g_4$				21.51	25.48
$h_2 g_1$	18.42	19.68	1.67	24.33	25.65
$h_2 g_2$	16.40	15.68	2.00	23.55	20.69
$h_2 g_3$	17.15	16.48	2.00	24.79	26.25
$h_2 g_4$	14.80	14.80	2.33	20.63	21.35
$h_3 g_1$	16.60	16.58	2.33	19.96	22.48
$h_3 g_2$	12.80	13.26	2.00	24.04	25.59
$h_3 g_3$	15.65	16.64	1.67	23.81	23.99
$h_3 g_4$	15.20	14.79	2.33	20.21	22.03
$F_{6, 12}$	1.38^{ns}	4.41^{ns}	0.18^{ns}	0.95^{ns}	3.42*
SE	0.09	0.08	0.005	1.31	2.17
CD	-	-	-	-	4.34

* Significant at 5 per cent
ns – Not significant

4.1.4 Seed yield and yield attributes

The results are presented in Tables 7 and 8.

4.1.4.1 Number of seeds per fruit

Number of vegetable harvests significantly influenced the number of seeds per fruit. The number of seeds per fruit was 448.96 in plants in which green fruit picking was not done (h_1) which was reduced to 418.61 when two vegetable harvests were done (h_3) causing 7.3 percent reduction. But h_1 and h_2 were on par.

The effect of growth regulator had shown that the number of seeds per fruit increased from 280. 53 for g_1 (zero ppm) to 404.17 for g_2 (100 ppm) and 538.20 for g_3 (200 ppm) with 41 and 92 per cent increase respectively over g_1. But with further increase in concentration to 300 ppm (g_4) there was a significant reduction in seed number to 519.38 causing 3.6 percent reduction over g_3.

H x G interaction was not significant.

4.1.4.2 Fruit to seed ratio

Fruit to seed ratio increased with increase in the number of vegetable harvest. Fruit to seed ratio was 68.04 for h_1 which was increased to 84.51 at h_2. Further increase in the number of harvest caused no significant increase in fruit to seed ratio.

The effects of growth regulator and H x G interaction were non significant.

4.1.4.3 Weight of seeds per fruit

Weight of seeds per fruit showed a proportionate reduction with increase in number of vegetable harvests. Seed weight per fruit was maximum for h_1 (zero vegetable harvest) which was significantly superior to h_2 and h_3.

The effect of growth regulator showed that the seed weight increased from 11.60g for zero ppm (g_1) to 25.06 g with increase in the concentration of growth regulator upto 200 ppm (g_3) recording an increase of 116 percent over g_1. g_3 was significantly superior to g_2 and g_1 but on par with g_4 (300 ppm).

The interaction effects had shown that when the plants were left as such without green fruit picking (h_1) the weight of seeds per fruit was 14.44g at g_1 (zero ppm ethephon) which was increased to 21.09 g by 100 ppm ethephon (g_2) and to 29.32 g by 200 ppm of ethephon (g_3) recording an increase of 46 and 103 percent respectively over g_1. In h_2 also the same trend was followed with 11.17 g for g_1 which was increased to 17.89 g for g_2 and 26.00 g for g_3 (an increase of 60 and 133 percent respectively over g_1). But in both the cases increase in the concentration of ethephon to 300 ppm caused a significant reduction in seed weight. At h_3 seed weight increased upto g_4 with 122 per cent increase over g_1. Here g_3 and g_4 were on par.

Among the interactions h_1g_3 gave the highest seed weight which was significantly superior to all other combinations. An increase in the number of harvests resulted in a decrease in seed weight per fruit.

4.1.4.4 Seed yield per plant

Seed yield per plant was maximum (286.54 g) for zero vegetable harvest (h_1) which was significantly superior to h_2 and h_3.

Among the levels of growth regulator g_3 (200 ppm) recorded the highest seed yield per plant which was significantly superior to g_2 and g_1 and was on par with g_4 (300 ppm).

The significant interaction effect of number of harvests and growth regulator on seed yield per plant showed when plants were left for seed collection without vegetable harvest (h_1) the seed yield was 81.72 g for g_1 (zero ppm) which was increased to 210.65g at g_2 (100 ppm) and to 439.94g at g_3 (200 ppm) recording an increase of 158 and 316 percent respectively over g_1. Similarly when one vegetable harvest was done (h_2), the seed yield per plant was 67.02 g for g_1. Here the increase in the concentration of growth regulator to 100 ppm did not cause a significant improvement in seed yield. The increase in seed yield was significant only at 200 ppm (g_3) i.e. an increase to 183.43 g recording 173 per cent increase over g_1. Under h_1 and h_2 increase in concentration of growth regulator to 300 ppm (g_4) cannot exert a positive effect. When two vegetable harvests were done (h_3) seed yield per plant was not affected by the increased concentration of growth regulator.

Among the treatment combinations highest seed yield per plant was recorded in h_1 g_3 which was on par with h_1 g_4 and significantly superior to all other combinations.

4.1.4.5 Seed yield per hectare

The results on seed yield per hectare followed the same trend as that of seed yield per plant.

Seed yield per hectare was maximum (152.84 kg) for zero vegetable harvest (h_1) which was significantly superior to h_2 and h_3.

Among the levels of growth regulator g_3 (200 ppm) recorded the highest seed yield (166.29 kg ha^{-1}) which was significantly superior to g_1 and g_2 but on par with g_4.

The interaction effect was significant. When the plants were left without vegetable harvest (h_1) the seed yield was 120.70 kg ha^{-1} for g_1 which was increased to 146.17 kg for g_2 and to 175.21 kg for g_3 (200 ppm) recording an increase of 21 and 45 percent respectively over g_1. But when one vegetable harvest was done (h_2) the seed yield was 121.30 kg for g_1 which showed a significant increase only at g_3 i.e., yield increased to 143.91 kg giving an increase of 18.6 percent ever g_1. When two vegetable harvest were done (h_3) the seed yield was 108.39 kg ha^{-1} for g_1 which showed a significant increase at g_3 recording 23 percent increase over g_1. In all the cases the increase in the concentration of growth regulator above 200 ppm did not result in a significant difference in seed yield.

Among the interactions highest seed yield per hectare was obtained in h_1 g_3.

Table 7 Main effect of harvest and growth regulator on seed yield and yield attributes

Treatment s	Number of seeds fruit^{-1}	Fruit to seed ratio	Weight of seeds fruit^{-1} (g)	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (kg)
h_1	448.96	68.04	22.74	286.54	152.84
h_2	439.12	84.51	19.88	129.82	141.55
h_3	418.61	92.59	16.03	85.85	135.84
$F_{2,4}$	15.55**	18.32**	263.31**	171.14**	49.42**
SE	11.72	5.02	0.09	15.12	3.11
CD	15.41	11.47	0.81	31.61	5.28
g_1	280.53	63.38	11.60	74.64	116.79
g_2	404.17	82.53	17.88	124.38	139.14
g_3	538.20	86.57	25.06	240.88	166.29
g_4	519.38	94.36	23.66	229.71	164.82
$F_{3,6}$	671.43**	3.06^{ns}	128.08**	74.14**	34.14**
SE	12.11	3.74	0.71	15.74	9.62
CD	15.91	-	1.88	32.59	13.94

** Significant at 1 per cent
ns Not significant

Table 8 Interaction effect of harvest and growth regulator on seed yield and yield attributes

Treatments	Number of seeds $fruit^{-1}$	Fruit to seed ratio	Weight of seeds $fruit^{-1}$ (g)	Seed yield $plant^{-1}$ (g)	Seed yield ha^{-1} (kg)
$h_1 g_1$	307.01	45.59	14.44	81.72	120.70
$h_1 g_2$	421.32	79.81	21.09	210.65	146.17
$h_1 g_3$	536.97	57.75	29.32	339.94	175.21
$h_1 g_4$	530.54	88.89	25.74	313.86	169.29
$h_2 g_1$	292.30	66.03	11.17	67.02	121.30
$h_2 g_2$	417.40	80.92	17.89	95.02	130.17
$h_2 g_3$	536.74	99.18	26.00	183.43	143.91
$h_2 g_4$	510.10	91.92	24.86	173.79	140.83
$h_3 g_1$	242.29	78.54	9.19	75.19	108.39
$h_3 g_2$	373.78	86.86	14.67	67.47	109.07
$h_3 g_3$	540.90	102.79	19.85	99.27	133.77
$h_3 g_4$	517.49	102.15	20.39	101.49	135.15
$F_{6, 12}$	2.97^{ns}	0.41^{ns}	8.73**	46.54**	4.86**
SE	25.31	10.72	0.41	9.01	2.11
CD	-	-	1.24	36.46	17.35

** Significant at 1 per cent
ns Not significant

4.1.5 Seed quality

The results are presented in Table 9.

4.1.5.1 1000 Seed weight

Number of vegetable harvests had no significant influence on thousand seed weight. However seed weight showed a slight reduction with increase in number of harvests. Thousand seed weight was 29.98 g for h_1 was reduced to 28.20 g for h_2 and to 26.58g for h_3.

Growth regulator had significant influence on thousand seed weight. Thousand seed weight was 26.40 for zero ppm of ethephon (g_1) which was increased to 31.19g for g_2 (100 ppm). A further increase in the concentration of growth regulator did not result in a positive effect.

H x G interaction was not significant.

4.1.5.2 seed viability

Seed viability was not influenced by the number of vegetable harvests, growth regulator and their interactions.

4.1.5.3 Germination percent

The effect of harvest, growth regulator and their interactions on germination percent was not significant.

Table 9 Main effect of harvest and growth regulator on seed quality parameters

Treatment	1000 seed weight (g)	Seed viability (percent)	Germination percent	Speed of germination
h_1	29.98	99.17 (84.77)	83.54 (66.06)	18.21
h_2	28.20	99.09 (84.53)	83.91 (66.35)	16.80
h_3	26.58	99.38 (85.48)	86.38 (68.34)	18.69
$F_{2,4}$	3.58^{ns}	0.85^{ns}	0.71^{ns}	0.04^{ns}
SE	1.03	1.23	0.79	0.52
g_1	26.40	99.05 (84.41)	83.74 (66.22)	22.91
g_2	31.19	99.11 (84.59)	84.86 (67.10)	17.99
g_3	28.77	99.33 (85.30)	85.13 (67.32)	14.51
g_4	26.67	99.33 (85.30)	84.72 (66.99)	19.18
$F_{3,6}$	7.51**	0.08^{ns}	0.57^{ns}	2.54^{ns}
SE	0.99	1.34	0.94	0.47
CD	2.81	-	-	-

** Significant at 1 per cent
ns Not significant
( ) Transformed values in angles

4.1.5.4 Speed of germination

Number of harvest, growth regulator and their interaction had no significant effect on speed of germination.

4.1.5.5 Seedling characters

The results on the effect of harvest, growth regulator and their interactions on parameters such as seedling shoot length, root length, vigour index and seedling dry weight are presented in Tables 10 and 11.

The effect of both the factors on seedling characters were not significant.

4.1.6 Economics of cultivation

The results are presented in Tables 12 and 13.

4.1.6.1 Net income

Maximum net return (58731.52 Rs ha^{-1}) was obtained when two vegetable pickings (h_3) were done which was significantly superior to both h_2 and h_1.

The effect of growth regulator on net income had shown that as the concentration of growth regulator increases the net income also increases significantly upto 200 ppm (g_3) i.e. an increase from Rs. 32287.39 for g_1 to Rs. 51567.72 for g_3. Further increase in the concentration of growth regulator to g_4 (300 ppm) does not resulted in a significant increase i.e., g_3 and g_4 were on par.

Table 10 Main effect of harvest and growth regulator on seedling characters

Treatment	Seedling shoot length (cm)	Seedling root length (cm)	Vigour index of seedling	Seedling dry weight (mg)
h_1	12.65	9.77	1877.88	23
h_2	12.86	9.92	1904.23	21
h_3	12.90	8.71	1869.83	22
$F_{2,4}$	0.32^{ns}	0.84^{ns}	0.03^{ns}	0.21^{ns}
SE	0.60	0.51	100.42	0.02
g_1	12.05	9.86	1771.91	21
g_2	13.09	9.54	1922.00	23
g_3	12.79	9.61	1906.59	23
g_4	13.27	9.65	1935.42	22
$F_{3,6}$	0.59^{ns}	0.27^{ns}	4.73^{ns}	1.89^{ns}
SE	0.79	0.37	125.31	0.03

ns - Not significant

Table 11 Interaction effect of harvest and growth regulator on seedling characters

Treatment	Seedling shoot length (cm)	Seedling root length (cm)	Vigour index of seedling	Seedling dry weight (mg)
$h_1 g_1$	11.14	8.64	1810.12	23
$h_1 g_2$	13.96	10.05	1927.15	26
$h_1 g_3$	10.97	8.79	1699.19	20
$h_1 g_4$	14.52	11.58	1975.79	23
$h_2 g_1$	12.94	8.94	1988.94	18
$h_2 g_2$	12.22	10.34	1825.41	23
$h_2 g_3$	13.57	10.89	1907.40	23
$h_2 g_4$	12.73	9.51	1839.19	21
$h_3 g_1$	12.06	9.60	1844.89	21
$h_3 g_2$	13.11	8.24	1878.44	20
$h_3 g_3$	13.85	9.13	1936.91	25
$h_3 g_4$	12.57	7.85	1895.67	22
$F_{6,12}$	3.60*	1.94^{ns}	2.99^{ns}	0.42^{ns}
SE	1.12	0.09	98.72	0.01
CD	2.44	-	-	-

* Significant at 5 per cent
ns – Not significant

Table 12 Main effect of harvest and growth regulator on economics of cultivation

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B : C ratio
h_1	64059.67	91781.50	27721.83	1.4
h_2	58298.67	104554.79	46256.12	1.9
h_3	56986.17	115717.69	58731.52	2.2
$F_{2,4}$	-	-	215.77**	150.14**
SE	-	-	970.41	0.001
CD	-	-	4170.78	0.10
g_1	48454.84	80742.23	32287.39	1.66
g_2	58286.71	98579.21	40292.50	1.69
g_3	66172.93	117740.65	51567.72	1.84
g_4	66180.36	116978.69	50798.34	1.80
$F_{3,6}$	-	-	17.62**	5.35*
SE	-	-	874.24	0.0014
CD	-	-	8042.37	0.15

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

Table 13 Interaction effect of harvest and growth regulator on economics of cultivation

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B : C ratio
$h_1 g_1$	51494.40	72722.00	21227.60	1.4
$h_1 g_2$	62856.93	87702.00	24845.07	1.4
$h_1 g_3$	70817.87	105124.00	34306.13	1.5
$h_1 g_4$	71069.46	101578.00	30508.53	1.4
$h_2 g_1$	47397.08	79343.51	31946.44	1.7
$h_2 g_2$	56734.27	107231.21	50496.94	1.9
$h_2 g_3$	64447.87	123241.20	58793.33	1.9
$h_2 g_4$	64615.47	118403.23	53787.76	1.9
$h_3 g_1$	46473.07	90161.21	43688.15	2.0
$h_3 g_2$	55268.93	110804.43	55535.49	2.2
$h_3 g_3$	63346.53	124950.23	61603.69	2.0
$h_3 g_4$	62856.13	123954.87	61098.74	2.2
$F_{6, 12}$	-	-	7.95**	1.81^{ns}
SE	-	-	3215.24	0.007
CD	-	-	12010.74	-

** Significant at 1 per cent
ns Not significant

The interaction effect of harvest and growth regulator revealed when no vegetable harvest was done (h_1) the net income was only Rs. 21227.60 for g_1 (zero ppm) and increased to Rs. 34306.13 by increasing the concentration of growth regulator to 200 ppm (g_3) giving an increase of 62 percent. When one vegetable harvest was done (h_2) the net income was 31946.44 Rs. ha-1 at g_1 which was increased to 58793.33 Rs. ha^{-1} at g_3 (200 ppm) recording 84 percent increase. At h_3 also highest net income of Rs. 61603.60 was observed at g_3 (200 ppm) which was significantly superior to g_4, g_2 and g_1. At all levels of harvests an increase in the concentration of growth regulator above 200 ppm did not result in a positive effect.

Among the interactions the combination h_3 g_3 gave the highest net income.

4.1.6.2 Benefit-Cost ratio

B : C ratio exhibited a significant increase with the increase in the number of vegetable harvests. Highest B : C ratio was recorded when two vegetable harvests were done (h_3) which was significantly superior to h_2 and h_1.

The effect of growth regulator showed that B : C ratio was only 1.7 for g_1 (zero ppm) and was increased to 1.9 at g_3 (200 ppm). Further increase in the concentration of growth regulator did not result in a positive effect.

The interaction H x G was not significant.

4.2 Experiment II

The effect of stages of harvest and time of seed extraction on seed yield and quality.

4.2.1 Fruit to seed ratio

The results are presented in Tables 14 and 15.

Fruit to seed ratio was highest when the fruits were harvested at 30 DAF (s_2) which was on par with harvesting at 45 DAF (s_3) and significantly superior to the fruits harvested at 15 DAF. (s_1).

Result on time of seed extraction showed that fruit to seed ratio was highest when seeds were stored for six days before seed extraction (r_3) which was significantly superior to r_1, r_2 and r_4.

The interaction of stages of harvesting and time of seed extraction revealed when the fruits were harvested at 15 DAF (s_1) fruit seed ratio was 56.75 when extracted on the same day of harvest (r_1) which was increased to 80.30 when extracted three days after harvest (r_2). Increase in the period of fruit storage upto six days (r_3) does not bring about a significant change but when the fruits were stored for nine days (r_4) there was significant reduction in the ratio reaching almost equal to that at r_1. When the fruits were harvested at 30 DAF (s_2) highest fruit to seed ratio was 99.13 at r_3 which was significantly superior to that at r_1, r_2 and r_4. When the fruits were harvested at 45 DAF (s_3) the ratio was highest at r_4 (extraction of seed nine days after harvest) i.e., 104.09 which was on par with r_3 but significantly superior to r_1

and r_2. However the highest fruit to seed ratio was observed in s_3 r_4 which was on par with s_2 r_1 and s_2 r_3 and significantly superior to all other combinations.

4.2.2 Number of seeds per fruit

Number of seeds per fruit was not influenced by the stages of fruit harvest, time of seed extraction and their interactions (Tables 14 and 15).

4.2.3 Weight of seeds per fruit

The results are presented in Tables 14 and 15.

Seed weight per fruit was 10.42 g when the seeds were harvested at 15 DAF (s_1) which was increased to 16.59 g at 30 DAF (s_2). Further delaying of harvest does not bring about a significant increase.

Maximum seed weight per fruit (15.45g) was observed when seeds were extracted nine days after harvest (r_4) which was significantly superior to r_3, $r_2$and r_1.

The interaction effect of stages of harvest and time of seed extraction showed that when the fruits were harvested at 15 DAF (s_1) and extracted on the same day of harvest (r_1) the seed weight per fruit was only 7.79 g which was increased with increase in time taken for extraction and recorded a weight of 13.03g when extracted nine days after harvest. When the fruits were harvested at 30 DAF (s_2) only r_4 could produce a significant increase in seed weight over r_1 recording 17 percent increase. But when fruits were harvested at 45 DAF (s_3), the storage of fruits intact before seed extraction

Table 14 Main effect of stages of harvesting and time of seed extraction on seed yield

Treatment	Fruit to seed ratio	Number of seeds per fruit	Weight of seeds fruit^{-1} (g)
s_1	67.58	466.62	10.42
s_2	84.38	460.33	16.59
s_3	83.78	438.89	16.48
$F_{2, 22}$	6.674**	1.568^{ns}	75.059**
SE	3.689	11.612	0.408
CD	10.821	-	1.195
r_1	67.56	450.91	13.38
r_2	76.94	460.58	14.51
r_3	91.75	434.12	14.66
r_4	78.08	473.51	15.45
$F_{3, 22}$	5.471**	1.509 ^{ns}	3.309*
SE	4.259	13.406	0.408
CD	12.491	-	1.38

** Significant at 1 per cent
* Significant at 5 per cent
ns Not significant

Table 15 Interaction effect of stages of harvesting and time of seed extraction on seed yield

Treatment	Fruit to seed ratio	Number of seeds per fruit	Weight of seeds fruit^{-1} (g)
$s_1 r_1$	56.75	486.51	7.79
$s_1 r_2$	80.30	453.40	10.19
$s_1 r_3$	77.75	453.07	10.51
$s_1 r_4$	55.52	473.50	13.03
$s_2 r_1$	87.03	451.27	14.98
$s_2 r_2$	76.74	459.87	16.98
$s_2 r_3$	99.13	446.77	16.88
$s_2 r_4$	74.64	483.39	17.54
$s_3 r_1$	58.89	420.94	17.19
$s_3 r_2$	73.77	468.47	16.34
$s_3 r_3$	98.36	402.51	16.58
$s_3 r_4$	104.09	463.63	15.79
$F_{6, 22}$	4.155**	0.708^{ns}	2.775*
SE	7.378	23.22	0.815
CD	21.642	-	2.391

** Significant at 1 per cent
* Significant at 5 per cent
ns Not significant

did not bring about any significant change in the weight of seeds per fruit. Among the interactions s_2r_4 recorded the highest seed weight per fruit.

4.2.4 1000 seed weight

The results are presented in Tables 16 and 17.

Stage of harvest had significant influence on 1000 seed weight. Thousand seed weight was maximum (31.68 g) when the fruits were harvested at 30 DAF (s_2) which was significantly superior to that harvested at 15 DAF (s_1) but on par with s_3 (45 DAF). s_2 showed 49 per cent increase over s_1.

The effect of time of seed extraction and the interaction S x R were not significant.

4.2.5 Seed viability

The results are presented in Tables 16 and 17.

Seed viability was maximum (99.87 per cent) at both s_2 and s_3 which were significantly superior to s_1.

Among the time of seed extraction, extraction nine days after harvest (r_4) recorded the highest seed viability (99.72 per cent) which was significantly superior to r_3, r_2 and r_1.

The significant interaction effects had shown when the fruits were harvested at 15 DAF (s_1) seed viability was only 26.67 per cent when extracted on the same day of harvest (r_1). This was increased to 45.00 percent when extracted three days after harvest (r_2), to 58.75 percent when stored for six days before seed extraction and 99.17 percent when extracted nine days after harvest recording an increase of 35.5, 88.9 and 172.7 percent respectively over r_1. However when the fruits were harvested at 30 and 45 DAF, the storage of fruits did not cause any significant change in seed viability.

4.2.6 Germination percent

The results are presented in Tables 16 and 17.

Germination percent was highest (99.79 percent) when the fruits were harvested at 45 DAF (s_3) which was significantly superior to s_2 and s_1.

Among the time of seed extraction, r_4 (extraction of seed nine days after harvest) recorded the highest germination percent (97.78 percent) which was significantly superior to r_3, r_2 and r_1.

The interaction effect was significant. When the fruits were harvested at 15 DAF (s_1) germination percent was only 19.0 percent for the seeds extracted on the same day of harvest (r_1). This was increased to 39. 33 percent at r_2, 54.33 per cent at r_3 and 79.74 at r_4 recording a spectacular increase of 50, 110 and 208 percent respectively over r_1. When the fruits were harvested at 30 (s_2) and 45 DAF (s_3) time of seed extraction caused no significant difference on germination percent.

4.2.7 Speed of germination

The results are presented in Tables 16 and 17.

Table 16 Main effect of stages of harvesting and time of seed extraction on seed quality parameters

Treatment	1000 seed weight (g)	Seed viability (per cent)	Germination percent	Speed of germination
s_1	21.26	60.98 (51.34)	55.29 (48.04)	17.16
s_2	31.68	99.87 (87.97)	97.83 (81.53)	37.07
s_3	30.38	99.87 (87.97)	99.79 (87.37)	37.04
$F_{2,22}$	75.988**	636.63**	341.38**	144.83**
SE	0.651	0.893	1.36	0.954
CD	1.911	2.619	3.99	2.799
r_1	26.37	75.56 (60.37)	72.28 (58.23)	26.49
r_2	27.98	81.67 (64.65)	79.50 (63.08)	28.56
r_3	28.32	91.03 (72.57)	87.67 (69.44)	29.59
r_4	28.42	99.72 (86.97)	97.78 (81.43)	37.04
$F_{3,22}$	1.615^{ns}	105.83**	48.67**	17.39**
SE	0.752	1.031	1.57	1.102
CD	-	1.786	4.609	3.232

** Significant at 1 per cent
ns Not significant
( ) Transformed values in angles

Table 17 Interaction effect of stages of harvesting and time of seed extraction of seed quality parameters

Treatment	1000 seed weight (g)	Seed viability (per cent)	Germination percent	Speed of germination
$s_1 r_1$	17.90	26.67 (31.09)	19.00 (25.84)	4.43
$s_1 r_2$	20.53	45.00 (42.13)	39.33 (38.84)	8.34
$s_1 r_3$	21.90	73.08 (58.75)	66.00 (54.33)	18.93
$s_1 r_4$	24.70	99.17 (84.77)	96.83 (79.74)	36.93
$s_2 r_1$	31.17	99.87 (87.97)	97.83 (81.53)	38.12
$s_2 r_2$	32.40	99.87 (87.97)	99.13 (84.65)	38.73
$s_2 r_3$	31.77	99.87 (87.97)	97.00 (80.03)	35.23
$s_2 r_4$	31.4	99.87 (87.97)	97.33 (80.59)	36.18
$s_3 r_1$	30.03	99.87 (87.97)	99.87 (87.97)	36.94
$s_3 r_2$	31.00	99.87 (87.97)	99.87 (87.97)	38.60
$s_3 r_3$	31.30	99.87 (87.97)	99.87 (87.97)	34.62
$s_3 r_4$	29.17	99.87 (87.97)	99.17 (84.90)	38.00
$F_{6, 22}$	1.92^{ns}	105.84**	52.49**	21.09**
SE	1.303	1.786	2.724	1.909
CD	-	5.238	7.976	5.589

** Significant at 1 per cent
ns Not significant
( ) Transformed values in angles

Speed of germination was only 17.16 when the fruits were harvested at 15 DAF (s_1) which showed a significant increase to 37.07 at 30 DAF (s_2). A further delay in harvesting of fruits to 45 days (s_3) did not cause any change in speed of germination.

Among the time of seed extraction maximum speed of germination (37.04) was observed when the seeds were extracted nine days after harvest (r_4) which was significantly superior to r_1, r_2 and r_3. r_1, r_2 and r_3 were on par.

The interaction effect of stages of harvest and time of seed extraction were significant. When the fruits were harvested at 15 DAF (s_1) the speed of germination was only 4.43 at r_1 which was increased to 8.34 at r_2, 18.93 at r_3 and to 36.93 at r_4 (extraction nine days after harvest) recording a tremendous increase over r_1. When the fruits were harvested on 30 DAF (s_2) and 45 DAF (s_3) the storage of fruits before seed extraction did not result in significant difference in speed of generation. However maximum speed of germination was recorded by the combination s_2r_2.

4.2.8 Seedling characters

The results are presented in Tables 18 and 19.

4.2.8.1 Seedling shoot length

Seedling shoot length was highest (14.12cm) when the fruits were harvested at 45 DAF which was on par with s_2 (harvesting at 30 DAF) and significantly superior to harvesting at 15 DAF (s_1).

Table 18 Main effect of stages of harvesting and time of seed extraction on seedling characters

Treatment	Seedling shoot length (cm)	Seedling root length (cm)	Vigour index	Seedling dry weight (mg)
s_1	10.44	5.86	1050.46	13
s_2	13.63	8.48	2161.96	23
s_3	14.12	9.54	2363.33	26
$F_{2,22}$	63.26**	31.69**	357.16**	116.00**
SE	0.251	0.337	37.41	0.06
CD	0.737	0.988	109.742	1.9
r_1	11.26	7.10	1588.79	19
r_2	12.29	7.59	1681.54	19
r_3	13.36	8.29	1896.74	23
r_4	14.34	8.85	2267.27	21
$F_{3,22}$	19.99**	3.91**	48.69**	7.59**
SE	0.29	0.389	43.20	0.07
CD	0.851	1.141	126.71	2.2

** Significant at 1 per cent

Table 19 Interaction effect of stages of harvest and time of seed extraction on seedling characters

Treatment	Shoot length (cm)	Root length (cm)	Vigour index	Seedling dry weight (mg)
$s_1 r_1$	5.41	3.45	191.00	4.3
$s_1 r_2$	8.86	5.95	577.38	8.5
$s_1 r_3$	13.11	6.18	1280.63	18.7
$s_1 r_4$	14.48	7.86	2152.85	19.7
$s_2 r_1$	13.37	8.14	2104.04	23.0
$s_2 r_2$	13.94	7.85	2161.91	23.7
$s_2 r_3$	13.07	9.06	2145.92	21.0
$s_2 r_4$	14.14	8.86	2235.96	22.7
$s_3 r_1$	14.99	9.72	2471.33	28.7
$s_3 r_2$	14.08	8.97	2305.33	24.3
$s_3 r_3$	13.89	9.62	2263.67	28.7
$s_3 r_4$	14.50	9.84	2413.00	22.0
$F_{6, 22}$	25.38**	2.22^{ns}	43.15**	17.87**
SE	0.502	0.674	74.83	0.13
CD	1.473	-	219.47	3.7

** Significant at 1 per cent
ns Not significant

The results on time of seed extraction showed that seedling shoot length was maximum (14.34 cm) at r_4 which was significantly superior to r_3, r_2 and r_1. r_3, r_2 and r_1 were on par.

The interaction effect of stages of harvest and time of seed extraction on seedling shoot length was significant. When the fruits were harvested at 15DAF (s_1) the seedlings produced longest shoot (14.48cm) with the seeds extracted nine days after harvest (r_4) which was significantly superior to all other combinations except s_1 r_3. Storage of fruit before seed extraction did not influence the seedling shoot length when the fruits were harvested at 30 and 45 DAF.

4.2.8.2 Seedling root length

Seedling root length was highest (9.54cm) at s_3 which was significantly superior to s_1 and s_2.

When the seeds were extracted after storing the fruits for nine days (r_4) the shoot length was maximum which was significantly superior to r_1 and r_2 which were on par with r_3.

s x r interaction was not significant.

4.2.8.3 Vigour Index

Highest vigour index of 2363.33 was observed when the fruits were harvested at 45 DAF (s_3) which was significantly superior to harvesting at 30 and 15 DAF (s_2 and s_1 respectively).

Highest vigour index of 2267.27 was observed when the seeds were extracted nine days after harvest (r_4) which was significantly superior to other levels.

The results on interaction revealed that at 15 DAF, the highest vigour index was recorded at r_4 which was significantly superior to all other levels. When the fruits were harvested an 30 DAF (s_2) and 45 DAF (s_3), the time of seed extraction caused no significant variation in vigour index. Among the combinations highest vigour index was recorded by the combination s_3r_1 which was on par with s_3r_2, s_3r_3 and s_3r_4 but significantly superior to all other combinations.

4.2.8.4 Seedling dry weight

Seedling dry weight recorded maximum value of 26 mg when the fruits were harvested 45 DAF (s_3) which was significantly superior to both s_2 and s_1.

The result on the time of seed extraction have shown that the seedling dry weight was highest when the seeds were extracted six days after harvest (r_3) which was on par with r_4 but significantly superior to r_2 and r_1.

The interaction of stages of harvest and time of seed extraction had shown that when the fruits were harvested at 15 DAF (s_1), the seedling dry weight was only 4.3 mg when the seeds were extracted on the same day of harvest (r_1) which was increased to 8.5 and 18.7 mg respectively for r_2 and r_3 recording 97 and 100 per cent increase over r_1. However s_1r_4 and s_1r_3 were on par. At s_2 and s_3 levels storage of fruits prior to seed extraction showed no significant variation in seedling dry weight.

DISCUSSION

5. DISCUSSION

The results of the investigation conducted at the College of Agriculture, Vellayani to assess the influence of vegetable harvest and growth regulator on seed yield and quality and also to standardise the physiological stage of maturity are discussed hereunder.

In vegetables among the several factors that account for the yield and quality of seeds, the number of vegetable harvests have a profound influence. Growth regulators especially ethephon is reported to have a significant influence on seed yield in many vegetable crops especially cucurbits.

The mode of action of ethephon is such that in an aqueous system above pH 4.0 it immediately releases ethylene. As the plant cells usually have a pH around 6.0 the chemical breaks down releasing ethylene (Draber, 1977). Ethylene, the simplest unsaturated hydrocarbon, regulates growth and development to a considerable extent. The primary reaction of ethylene influences the metabolism of plants which causes the different physiological plant responses.

5.1 Effect of number of vegetable harvests and growth regulator on seed yield and qualtiy

5.1.1 Growth characters

Increase in the number of vegetable harvests caused the elongation of the vine, the longest (190.83 cm) being in two vegetable harvest (h_3) and the shortest (156.60 cm) in zero vegetable harvest (h_1) (Table 2). This is in agreement with the work of Devi (1999) in bittergourd. The elongation of vine may be due to the stimulation of apical growth in plants with periodic removal of fruits by which the photosynthates get translocated to the growing tip instead of accumulating in fruits. Kamalanathan *et al.* (1968) reported that in bhindi if the pods are left to mature without green fruit picking the plants become stunted which explains the significant reduction in vine length at zero vegetable harvest. Similar results were also observed by Garris and Hoffman (1946) in bhindi.

A proportionate reduction in vine length was observed by increasing the concentration of ethephon with the longest (195.15 cm) in g_1 (zero ppm) and the shortest (172.05 cm) in g_4 (300 ppm). Similar results of reduced vine length by the application of ethephon was reported by Kumar and Peter (1986) in *Cucumis* sp. and by Das and Das (1996) in pumpkin. Application of other growth regulators like MH also causes reduction in vine length in cucurbits (Suresh and Pappiah, 1991). According to Singh *et al.* (1976) the reduction in vine length by the application of growth regulators is mainly due to the reduction in the synthesis of gibberellins in tissues which is a major promoter of cell division in meristematic region.

The number of branches per plant was affected by vegetable harvests very similar to that of vine length with the highest and lowest values for two and zero vegetable harvests respectively. Though not significant, the number of branches per plant showed an increasing trend by increasing the concentration of ethephon. Similar increase in number of branches per plant by growth regulators were also reported by Suresh and Pappiah (1991) in bittergourd with MH and Das and Das (1996) in pumpkin by ethephon. They suggested that the production of more number of branches are due to the ability of ethylene to break apical dominance.

LAI of the crop was increased by increasing the number of vegetable harvests form zero to two. Expansion of leaf area is reported to be a reflection of periodic removal of fruits (Sheeba, 1995). Production of more number of leaves with periodic picking of green fruits in bhindi is reported by Bhuibar *et al.* (1989). If a sink is available, the plants show a general tendency to translocate the photosynthates to the source. In zero vegetable harvest since the fruits (sink) are not removed periodically, the photosynthates always get accumulated in fruits and only less amount of photosynthates will be available for the source development.

LAI showed a proportionate increase with increase in the concentration of ethephon with the lowest value (1.06) in g_1 (zero ppm) and highest (1.16) in g_4 (300 ppm). This is in agreement with the work of Das and Das (1996) in pumpkin. Increase in LAI may be due to the production of more number of leaves per plant and due to the increased number of branches.

5.1.2 Fruit yield and yield attributes

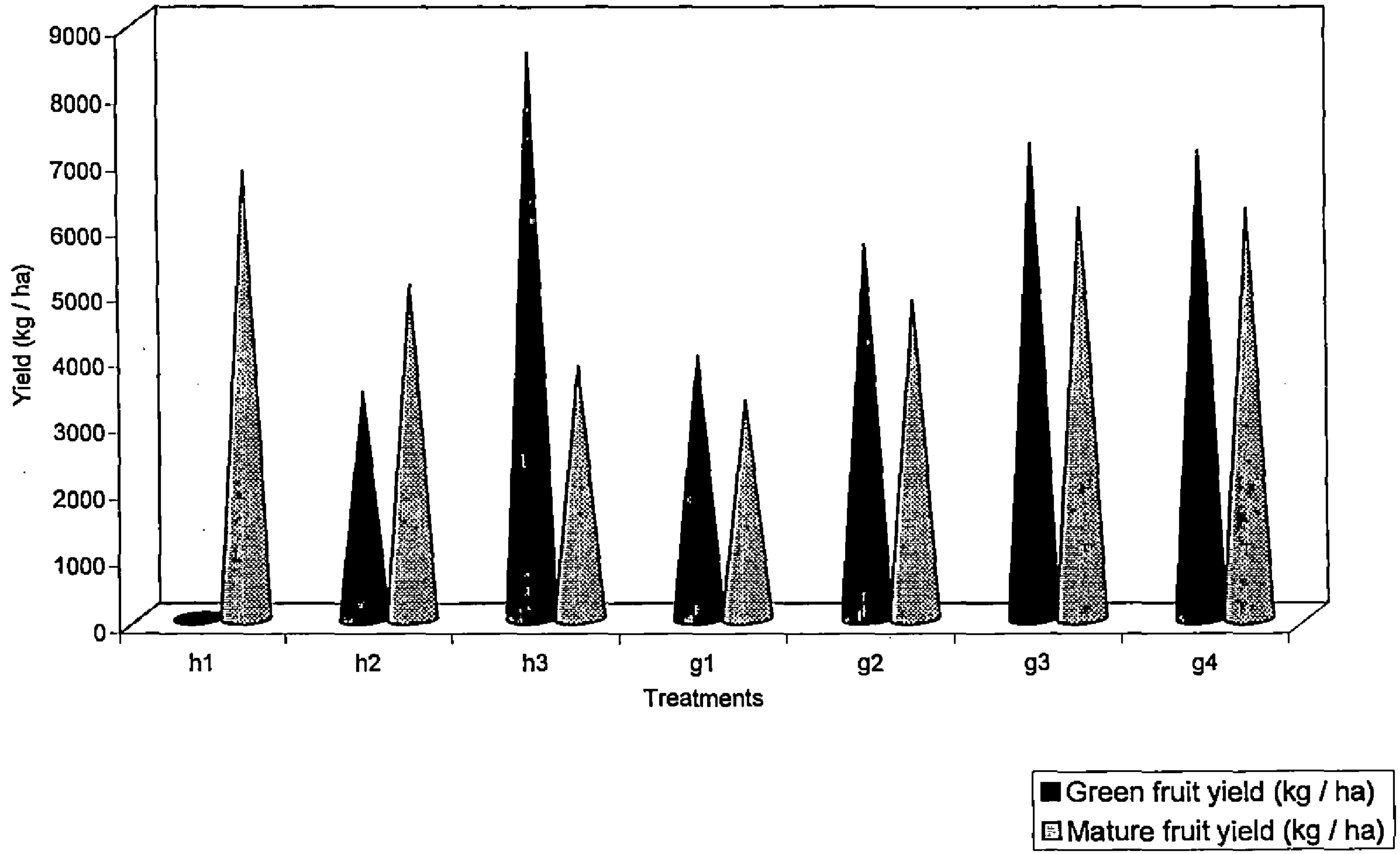
Increase in number of vegetable harvests caused a sharp increase in the number of green fruits per plant and total number of fruits harvested per plant (Table 4). This result is in accordance with the findings of Perkins *et al.* (1952), Madhava Rao (1953), Khalil and Hamid (1964), Kolhe and Chavan

(1967), Grewal *et al.* (1974) and Sheeba (1995) in bhindi and Devi (1999) in bittergourd. Developing and maturing fruits have an inhibitory effect on further development of flowers and fruits. In those crops where immature fruits are harvested at vegetable stage, this inhibitory mechanism will not be perceptible but in crops where ripe fruits are harvested this will be obvious. The vine strikes physiological balance at the threshold limit of maximum fruits it can carry to maturity. That is why the number of fruits per vine in a seed crop is less (Seshadiri, 1993).

Green fruit yield per plant and green fruit yield per hectare also followed the same trend as that for green fruit number. The green fruit yield per hectare was 3405.82 kg for h_2 and 8552.29 kg for h_3 recording almost 250 per cent increase over h_2 (Fig. 4). This result is in conformity with the observations of Madhava Rao (1953) and Bhuibar *et al.* (1989) in bhindi and Devi (1999) in bittergourd. Periodic removal of fruits make the cucurbits more productive when grown for immature fruits (Robinson and Decker-Walters, 1997). They also concluded that fruits act as a sink for nutrients and inhibit the development of additional fruits in plant if not removed.

The number and weight of green fruits per plant and green fruit yield recorded maximum values when ethephon was applied at a concentration of 200 pm (g_3) which was on par with g_4 (300 ppm). The number of green fruits per plant was increased from 6.5 (g_1) to 18.83 (g_3) recording an increase of 190 per cent over g_1. Weight of green fruits per plant also showed a spectacular increase. Green fruit yield per hectare was doubled when 200 ppm of ethephon was applied (Fig. 4). These results were in accordance with

Fig. 4 Effect of harvest and growth regulator on green and mature fruit yield



several earlier studies (Shanmughavelu *et al.*, 1973; Verma and Choudhary, 1980; Dubey 1983; Arora *et al.*, 1989; Sitaram *et al.*, 1989; Devadas and Ramadas, 1994 and Elizabeth, 1998). The increase in fruit yield by ethephon is due to higher female flower production. Ethephon releases ethylene directly into the plant tissues producing physiological changes leading to the suppression of male flowers and increased production of female flowers (Krishnamoorthy, 1981). Increased production of female flowers due to the application of ethephon narrowed down the sex ratio leading to the production of larger number of fruits. This is in line with the findings of El-Ghamainy *et al.* (1985), Arora *et al.* (1985) and Das and Das (1996).

The significant interaction effect of number of harvests and growth regulator on weight of green fruits per plant, green fruit yield per hectare and total number of fruits may be due to the cumulative effect of harvest and growth regulator.

The weight of mature fruits per plant as well as mature fruit yield per hectare showed a proportionate reduction with increase in the number of vegetable harvests (Fig. 4). Highest mature fruit yield was in zero vegetable harvest (6786.48 kg ha^{-1}). This is in accordance with the work of Sheeba (1995). In cucurbits, the first formed fruits will be bigger because of higher accumulation of photosynthates in early stages. Hence, smaller fruits might have formed on the plant at later stages. This attributes to the higher mature fruit yield in zero vegetable harvest (Devadas *et al.*, 1999). In one and two vegetable harvest, some of fruits were harvested at immature stage which may also be resulted in lower mature fruit yield in these treatments.

Weight of mature fruits per plant and mature fruit yield was highest when ethephon was applied at concentration of 200 ppm which was on par with 300 ppm. This may be due to the influence of ethephon in increasing the female flower production and subsequent production of fruits.

Maximum length and girth of fruits at harvest was recorded for one vegetable harvest (h_2) and the lowest for two vegetable harvests (h_3). The growing fruit is an active sink that derives and draws water and nutrients from other regions of the plant. In cucurbits, the first formed fruits will be bigger and they have a suppressing effect on the development of fruits formed subsequently (Devadas *et al.*, 1999). Hence smaller fruits might have formed on the plant at later stages due to the reduced accumulation of photosynthates. Moreover, in early stages plants are in the active growth stage which results in the production of larger fruits with better accumulation of photosynthates.

From the result it was seen that there was a reduction in fruit size due to the application of ethephone though not significant. This is in accordance with the findings of Verma *et al.* (1987) in pumpkin. Reduction in fruit size may be because, a higher number of fruits are produced by the application of ethephon and the photosynthates produced have to be partitioned to more number of fruits. So the fruit size is reduced.

Shelf life of green fruit was not influenced by number of vegetable harvests and growth regulator. The non-significant influence of ethephon on shelf life of fruits is in conformity with the work of Elizabeth (1998).

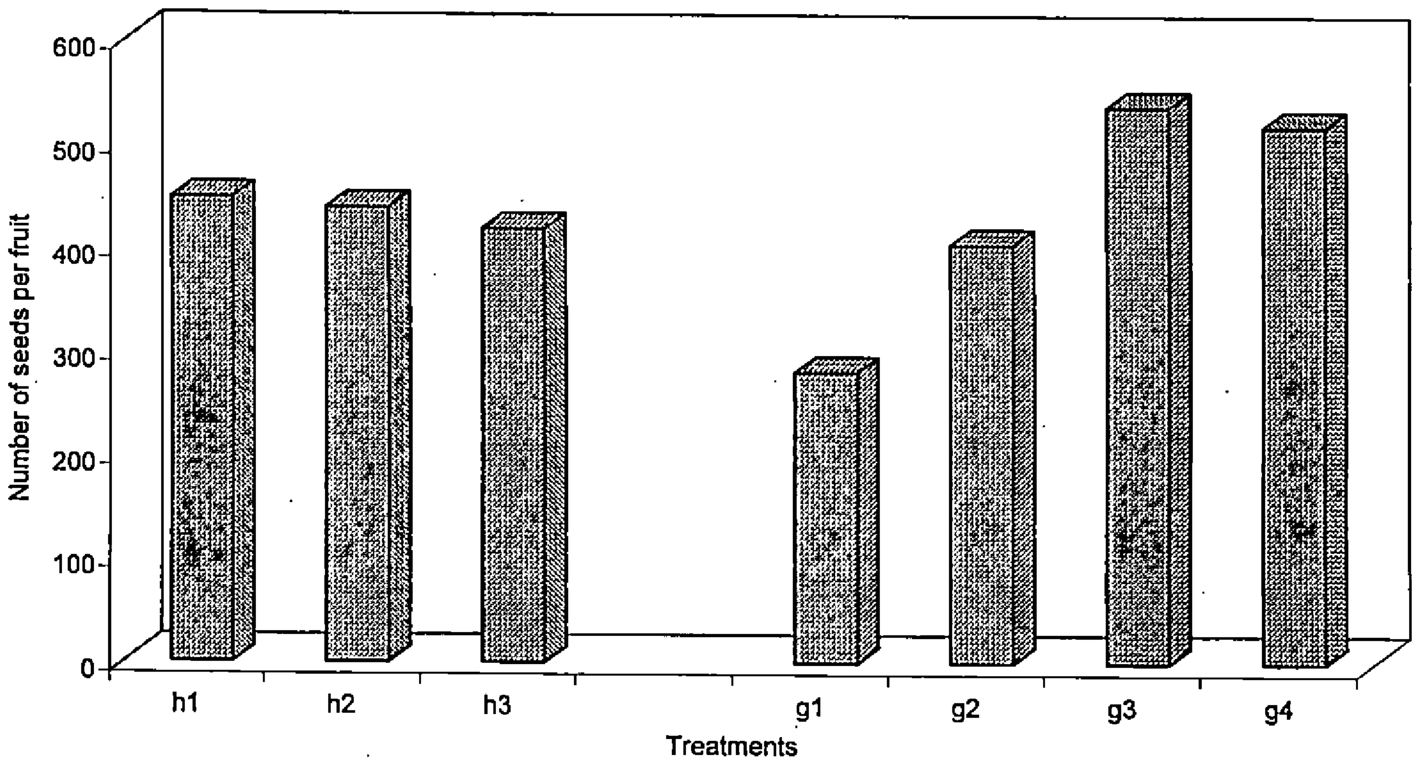
5.1.3 Seed yield and quality

Number and weight of seeds per fruit decreases with increase in number of vegetable harvests with the highest in plants which were left as such without green fruit picking (h_1) and lowest in two vegetable harvests (h_3) (Fig. 5). This is in conformity with the observations of Rode (1979), Velumani and Ramaswamy (1980), Deshmukhe and Tayde (1986) and Bhuibar *et al.* (1989) in bhindi and Devi (1999) in bittergourd. More number of seeds in zero vegetable harvest may be due to the better utilization of photosynthates for seed development, as the early-formed fruits are retained for seed.

A proportionate increase in number and weight of seeds per fruit was observed by increasing the concentration of ethephon to 200 ppm (g_3). Number of seeds per fruit reduced significantly when the concentration of ethephon was increased to 300 ppm (Fig. 5). But weight of seeds per fruit recorded highest value at 200 ppm which was on par with that at 300 ppm ethephon. This is in agreement with the works of Sitaram *et al.* (1989) in cucumber, Devadas and Ramadas (1994) in pumpkin and Gedam *et al.* (1996) in bittergourd. According to Uppar and Kulkarni (1989), increase in number and weight of seeds per fruit with the application of growth regulators is probably due to the inhibition of basipetal movement of auxins from fruits resulting in the proper utilization of auxins for the development of fruits and seeds by mobilization of nutrients from source to sink.

Seed yield per plant and seed yield per hectare were highest when the plants were left for seed collection without green fruit picking (h_1) (Table 8).

Fig. 5 Effect of harvest and growth regulator on number of seeds per fruit

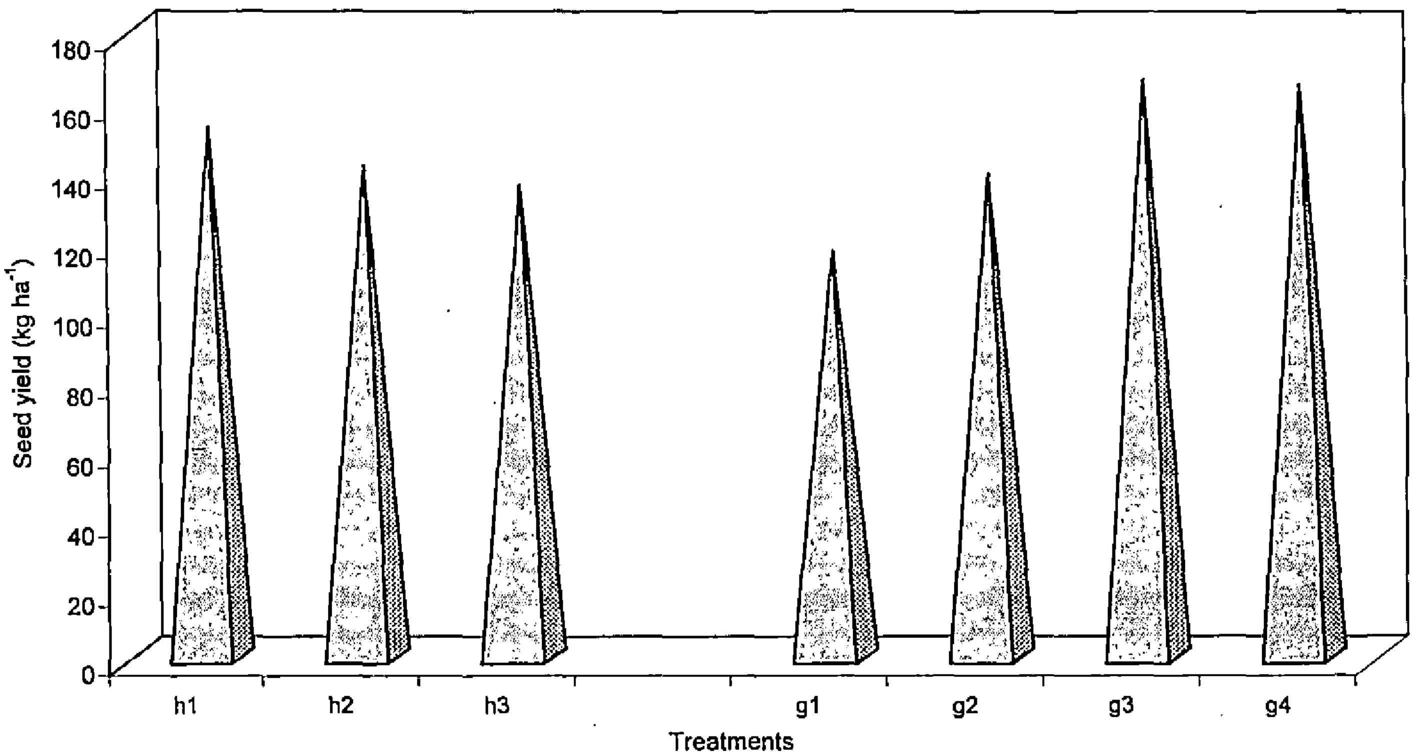


Highest seed yield was 152.84 kg ha^{-1} for h_1 which was 12.5 per cent more than two vegetable harvest (h_3) but on par with one vegetable harvest (h_2) (Fig. 6). This result is in agreement with the observations of Men'kova (1974) in cucumber and Sheeba (1995) in bhindi. This may be due to the higher seed number and seed weight per fruit for the plants left for seed collection and also due to the higher mature fruit yield observed for the treatment.

Seed yield per plant and per hectare were highest with the application of 200 ppm ethephon which was on par with that at 300 ppm. Seed yield of 240.88 g plant^{-1} and 166.29 kg ha^{-1} were obtained with the application of 200 ppm ethephon with an increase of 56 and 42 per cent respectively over zero ppm (Fig. 6). Increased seed yields due to the application of ethephon is in conformity with the reports of Sinha (1974) and Singh *et al.* (1976) in cauliflower, Edelstein *et al.* (1985), El-Beheidi *et al.* (1987) and Sitaram *et al.* (1989) in cucurbits. This may be due to the higher fruit yield, seed number and seed weight per fruit for the treatment.

Though the number of vegetable harvests had no significant influence on 1000 seed weight, highest thousand seed weight (29.98 g) was observed for zero vegetable (h_1) harvest and lowest (26.58 g) in two vegetable harvests (h_3). This may be due to the better accumulation of photosynthates in early formed fruits. There was a progressive decrease in 1000 seed weight with increase in the number of fruits harvested per plant. This is in accordance with the reports of Velumani and Ramaswamy (1980), Khan and Jaiswal (1988) and Bhuibar *et al.* (1989) in okra.

Fig. 6 Effect of harvest and growth regulator on seed yield (kg ha^{-1})

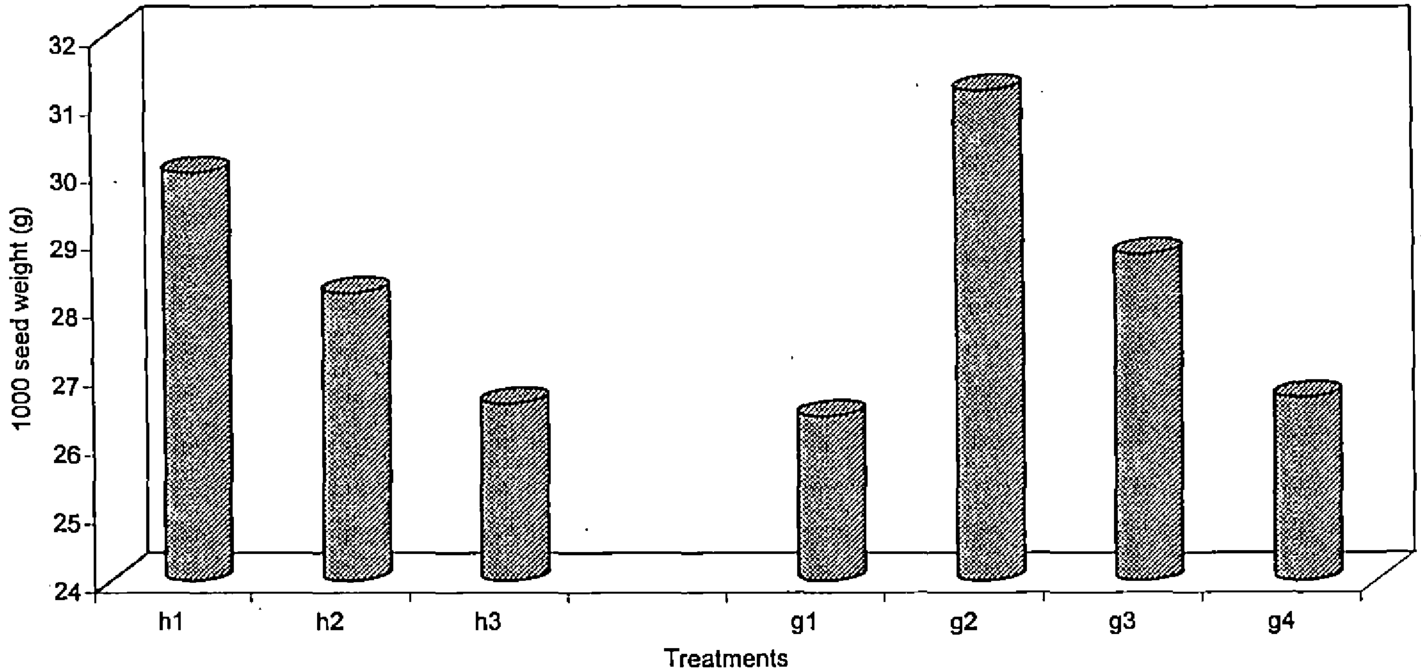


Though the effects were not significant, highest germination percentage, speed of germination and seed viability were obtained with two green fruit pickings (h_3). This is supported by the findings of Natraj *et al.* (1992), Sheeba (1995) and Singh and Kanwar (1995) in bhindi and Devi (1999) in bittergourd. The seedling characters such as seedling shoot length, root length and vigour index were highest for one vegetable harvest eventhough the effects were not significant. This is in conformity with the findings of Asokmehta and Ramakrishnan (1986) in chilli and Natraj *et al.* (1992) in bhindi. Seedling dry weight showed a reduction with increase in number of harvests with highest in zero vegetable harvest (Table 10). This may be due to higher seed weight obtained for the treatment by the better accumulation of photosynthates and is reflected further on seedling dry weight.

Growth regulator had significant influence on 1000 seed weight (Table 9). Among the levels of growth regulator g_2 (100 ppm) recorded the highest 1000 seed weight (31.19 g) which was significantly superior to zero and 300 ppm and on par with 200 ppm of ethephon (Fig. 7). This is in conformity with the observations of Sitaram *et al.* (1989) in cucumber and Gedam *et al.* (1996) in bittergourd. Seedling dry weight was also maximum for 100 ppm ethephon though not significant. This may be due to higher seed weight due to greater amount of accumulated food reserves.

Other seed quality parameters such as germination percent, seedling shoot and root length, vigour index and seed viability were not affected by growth regulator. The non significant influence of growth regulators on these

Fig. 7 Effect of harvest and growth regulator on thousand seed weight (g)



seed quality parameters were in conformity with the findings of Sitaram *et al.* (1989) in cucumber and Gedam *et al.* (1996) in bittergourd.

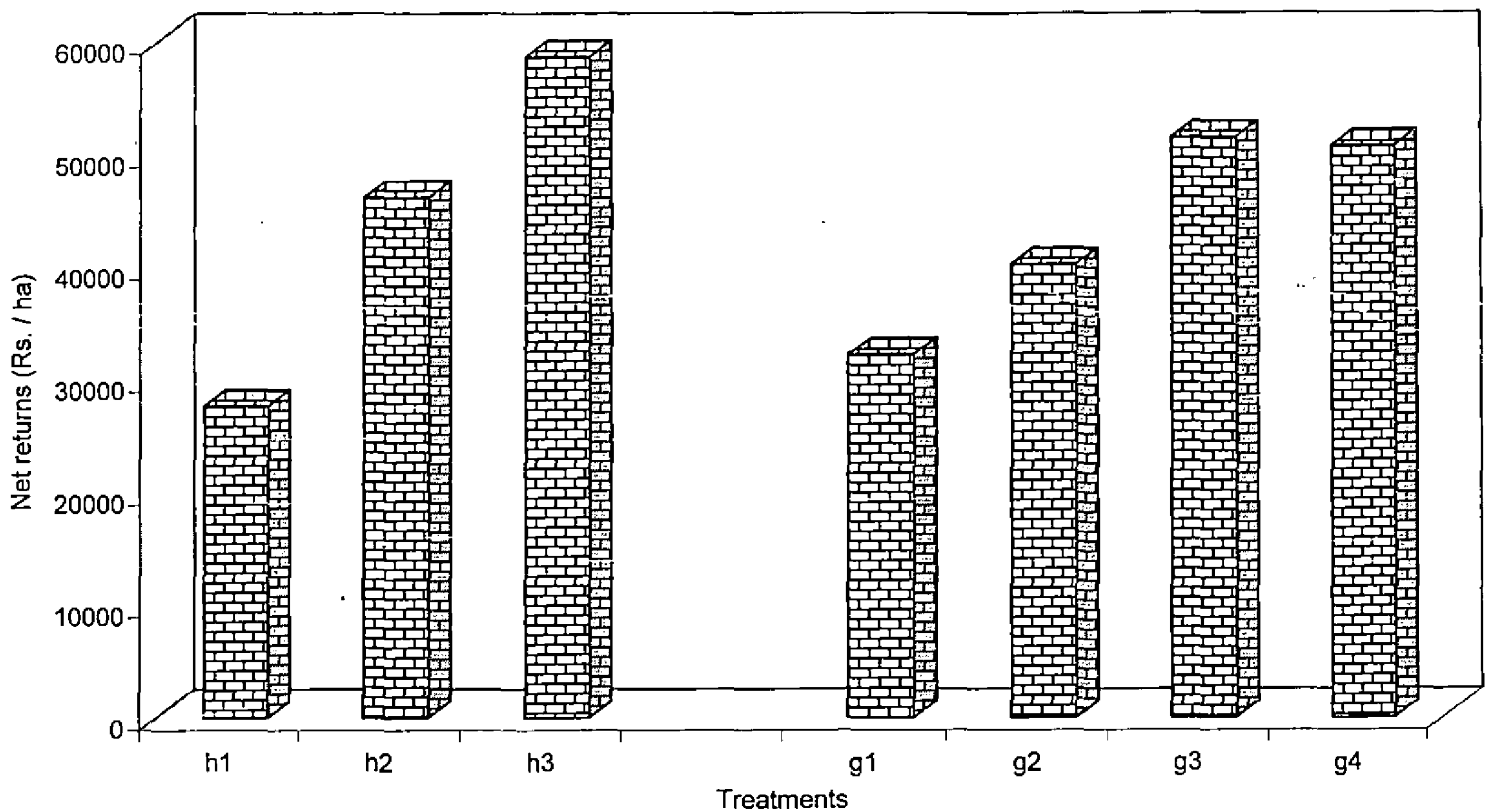
5.1.4 Economics of cultivation

The net income as well as the B : C ratio were significantly influenced by number of vegetable harvests and growth regulator. Highest net income and B : C ratio were obtained for h_3 (two vegetable harvest) because of higher fruit yield for the treatment as observed from the data (Table 12). Highest net income of Rs. 58731.52 ha^{-1} was obtained for two vegetable harvest which was 112 per cent more than that from zero vegetable harvest (Fig. 8). B : C ratio was 2.2 for h_3 as against 1.4 for h_1.

Among the levels of growth regulator highest net return Rs. 51567.72 ha^{-1} was recorded for g_3 (200 ppm) recording 60 per cent increase over g_1 (Fig. 8). B : C ratio was highest (1.84) for g_3. This is due to the higher fruit and seed yield observed in these treatments.

It is evident from the results that combining vegetable and seed production is possible as the quality of seed is not influenced by number of harvests. When economics is considered highest net return is obtained at two vegetable harvest. So in cucumber two vegetable harvests can be done along with seed production. Among the levels of ethephon, the concentration of 200 pm was most economical by giving maximum fruit and seed yields. Seed quality was not influenced by ethephon except for 1000 seed weight.

Fig. 8 Effect of harvest and growth regulator on net return (Rs. ha^{-1})



5.2 Effect of stages of seed harvest and time of seed extraction on seed yield and quality

One of the factors that affects seed quality and its subsequent performance is the stage of seed maturity at harvest. The level of viability and vigour is determined by the extent of seed development when the crop is harvested. It is well established that seed quality is highest at physiological maturity which proceeds harvestable maturity. According to Harrington (1972) physiological maturity is the developmental stage at which seeds achieve maximum vigour and viability and since nutrients are no longer entering the seeds from the plant seed senescence begins.

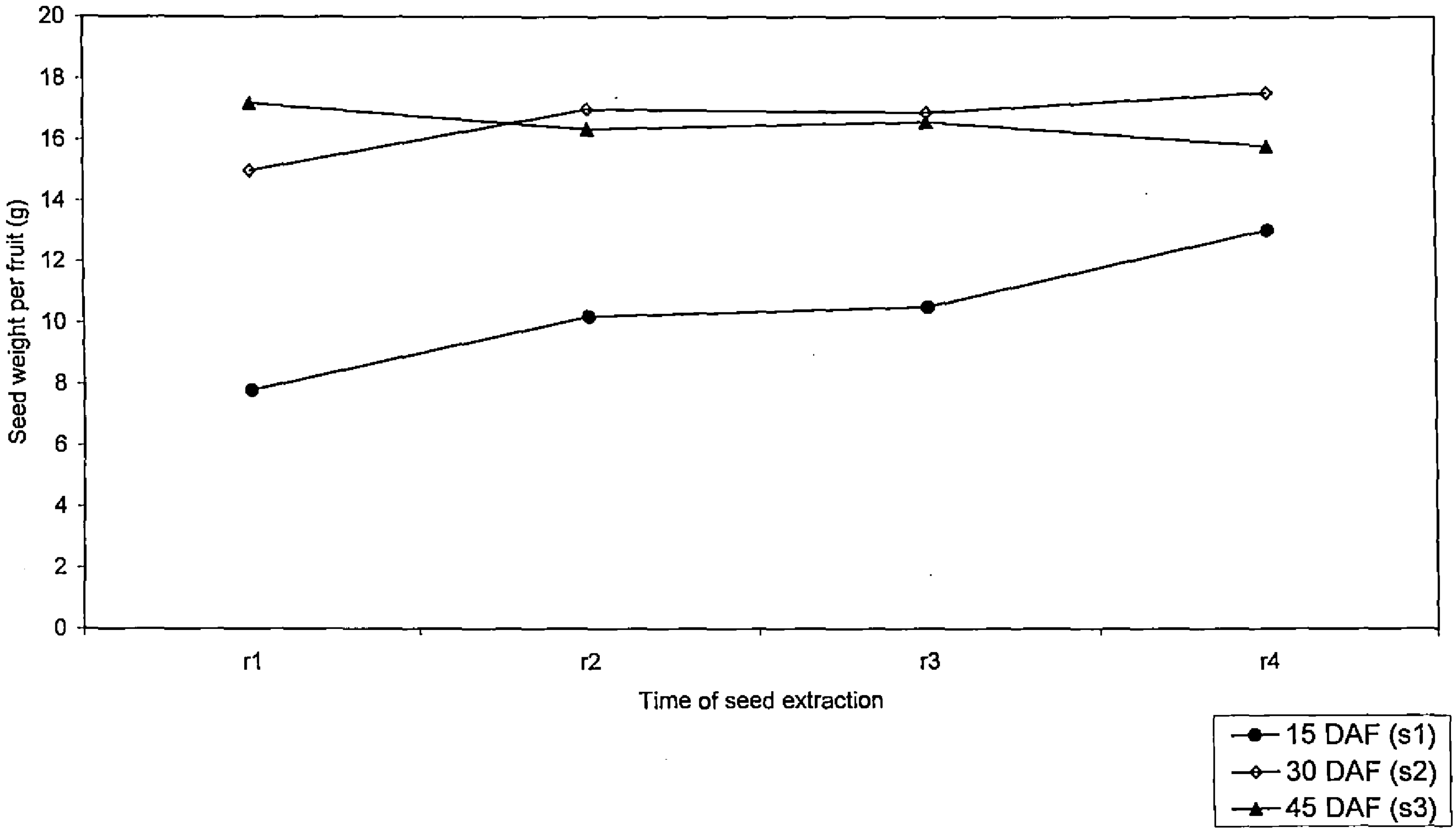
Fruit to seed ratio was increased with the advancement of stage of harvest. This may be because of the larger size of the fruits harvested at 30 and 45 DAF. Number of seeds per fruit was not influenced by the stage of harvest and storage of fruits intact before seed extraction. Similar observations were also reported by Harrington (1959) in muskmelon, Quagliotti *et al.* (1981) in chilli and Buriev (1987) in cucumber.

Weight of seeds per fruit showed a spectacular increase from 10.42 g to 16.59 g with the advancement of harvest from 15 to 30 DAF. But when harvesting was delayed upto 45 days the seed weight per fruit showed a slight reduction eventhough the reduction was not significant. Increase in seed weight per fruit upto physiological maturity is in accordance with the works of Patapova (1972) in cucumber, Shanmugaraj (1978) in lablab bean, Chandrasekaran (1979) in bottlegourd, Kanwar and Saimbhi (1987) in Bhindi and Naik *et al.* (1996) in chilli. Lower seed weight per fruit from the fruits harvested at immature stage may be due to large proportion of unfilled seeds and seeds with poor embryo development.

Seed weight per fruit showed a gradual increase when the fruits were stored for few days before seed extraction. The seed weight which was 13.37 g when extracted on the same day of harvest was increased to 15.45 g when the seed extraction was done nine days after fruit harvest. Similarly the seed weight from the fruits harvested at immature stage (15 DAF) also showed a spectacular increase to 13.03 g when extracted after storage for nine days as against 7.75 g when extracted on the same day of harvest showing 38 per cent increase (Table 15). The same trend was followed when the fruits were harvested at 30 DAF. But when harvesting was done at 45 DAF the storage of fruits intact before seed extraction caused a reduction in seed weight (Fig. 9). The improvement in seed weight from fruits harvested at immature stage and kept for few days were in agreement with the findings of Cochran (1943) in chilli, Young (1949) in butternut squash and Krishnaswamy (1991) in bittergourd. According to Robinson and Decker-Walters (1997) cucurbit seed will continue to develop even after the fruit is removed from the vine. So eventhough the fruits are picked at immature stage, best quality seeds are obtained when the fruits are stored intact for few days before extracting the seed.

The results also revealed marked influence of stage of fruit harvest on seed quality characteristics. There was successive increase in the thousand seed weight from 15 DAF (21.26 g) to a maximum at 30 DAF (31.68 g). 1000

Fig. 9 Effect of time of seed extraction on seed weight per fruit at different stages of harvest (g)

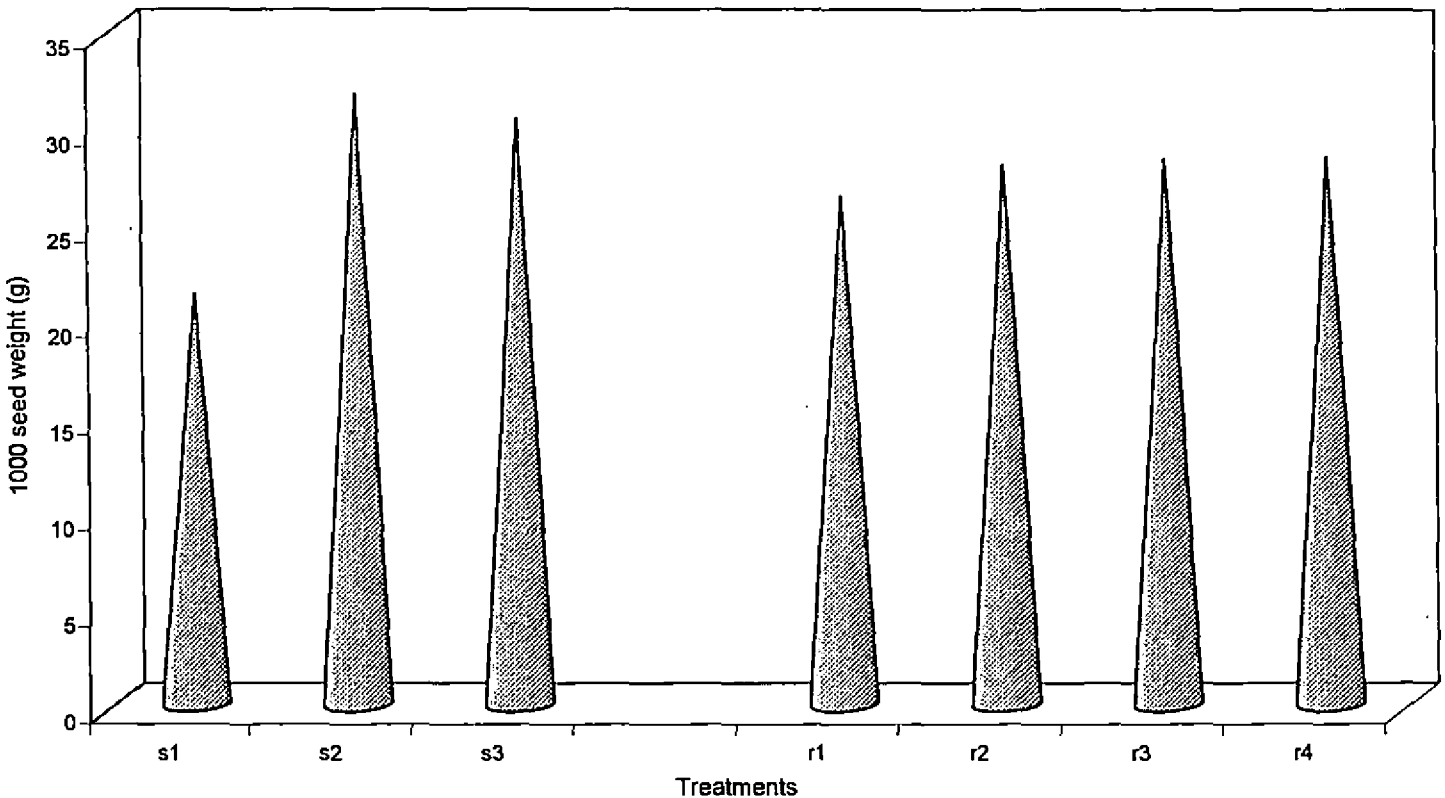


seed weight showed a gradual increase from 26.37 g by extraction of seed on the same day of harvest to 28.42 g when the fruits were kept intact for nine days before seed extraction (Fig. 10). This indicated that large amount of reserve food substances went on accumulating in the seeds till 30 DAF and thereafter no increase in 1000 seed weight was observed. This is in conformity with the findings of Asokmehta and Ramakrishnan (1986) in chilli.

Seed quality parameters like seed viability, germination percent, seedling shoot length, seedling root length, vigour index and seedling dry weight recorded highest values in seeds from fruits harvested at 45 DAF and on par with that at 30 DAF. The highest value of these parameters from the seeds harvested at physiological maturity is in agreement with the observations of Mc Alister (1943) and Garris and Hoffman (1946) in Bhindi, Harrington (1959) in muskmelon, Patapova (1972) in cucumber, Metha (1983) in chilli, Alvarenga *et al.* (1984) in watermelon, Naik *et al.* (1996) in chilli and Rakeshseth *et al.* (1999) in fodder cowpea.

Germination percent showed a spectacular increase from 55.29 at 15 DAF to 99.79 per cent with the advancement of harvest to 45 DAF. Seed viability showed an increase from 26.67 to 99.87 per cent from 15 to 45 DAF. Seedling shoot length and root length also showed a tremendous increase from 10.44 cm and 5.89 cm respectively at 15 DAF to 14.12 cm and 9.54 cm at 45 DAF. Seedling vigour index and dry weight recorded the lowest values at 15 DAF (1050.46 and 13 mg respectively) which was increased to a maximum of 2363.33 and 26 mg respectively at 45 DAF. There was an increase in the speed of germination from 17.16 at 15 DAF to reach a maximum of 37.07 at

Fig. 10 Effect of stages of harvest and time of seed extraction on 1000 seed weight (g)



30 DAF. However, a further delay in time of harvest to 45 days did not cause any significant influence on speed of germination. Harvesting the seeds before the attainment of physiological maturity recorded lesser viability and vigour potentials due to the presence of more number of immature seeds with relatively low degree of embryo development and high moisture content as reported by Jayaraj and Karivaratharaju (1992) in groundnut. Improvement in the quality of seed with the attainment of physiological maturity is reflected in seed quality parameters like germination percent, viability, speed of germination, seedling shoot and root length, vigour index and seedling dry weight. This indicated that the seeds are still undergoing rapid growth and maturation beyond 15 DAF. The accumulation of large quantities of reserve food substances during this development process enhanced the seed weight and hence an increase in other quality parameters.

When the seeds were extracted on the same day of harvest the germination was only 72.28 per cent. This increased gradually to 97.78 per cent when extracted nine days after fruit harvest. Such a spectacular increase was also observed in other seed quality parameters like speed of germination, seed viability, seedling shoot and root length, vigour index and seedling dry weight. The seeds from the fruits harvested at 15 DAF and extracted on the same day of harvest showed a germination of 19 per cent and was increased gradually to 96.83 percent with the advancement of storage of fruits before seed extraction to nine days (Fig. 11). Similar trend of tremendous increase in seedling shoot length, root length, vigour index, seedling dry weight, speed of germination and seed viability were recorded when the fruits harvested at 15

Fig. 11 Effect of time of seed extraction on germination per cent at different stages of harvest

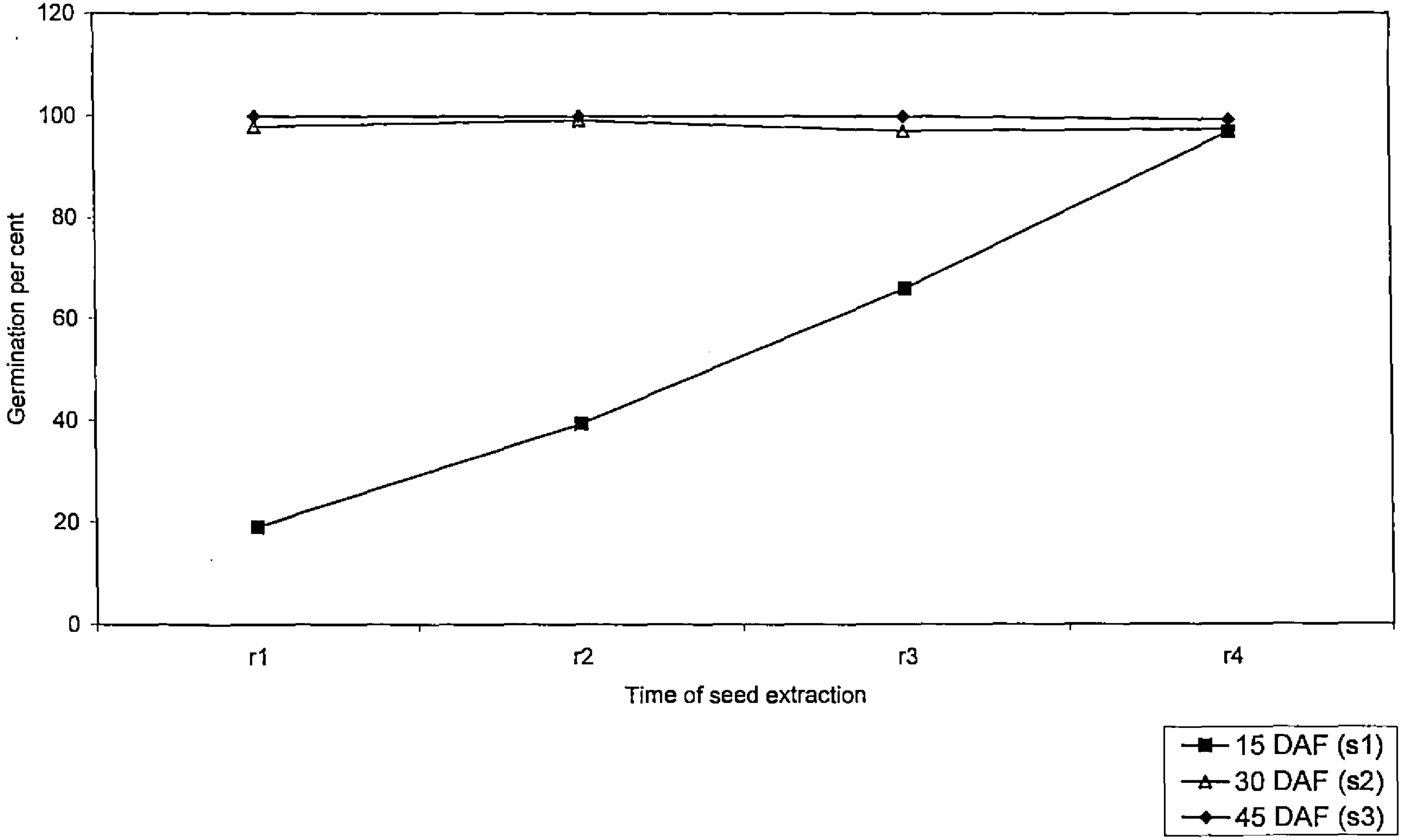


Fig. 12 Effect of time of seed extraction on speed of germination at different stages of harvest

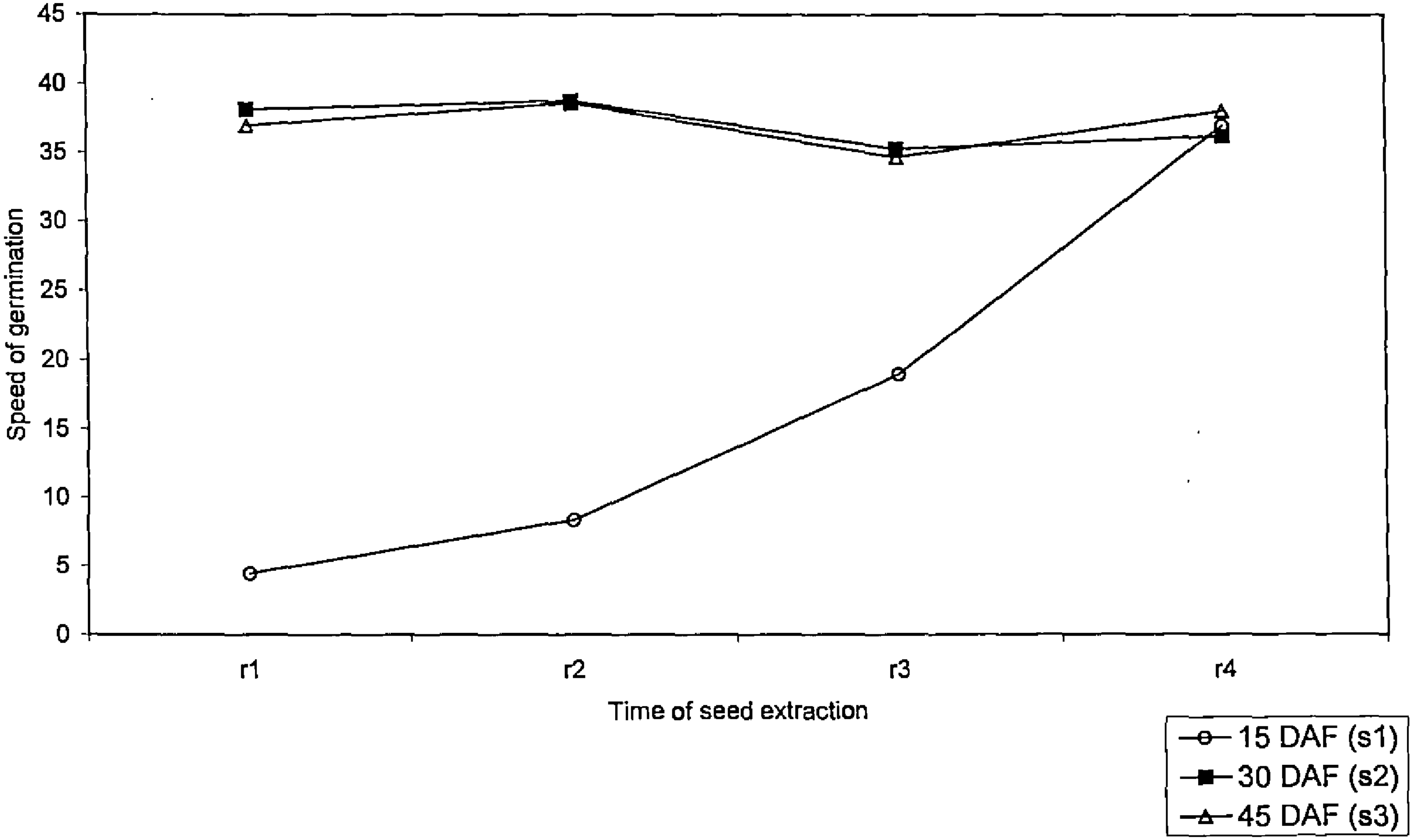
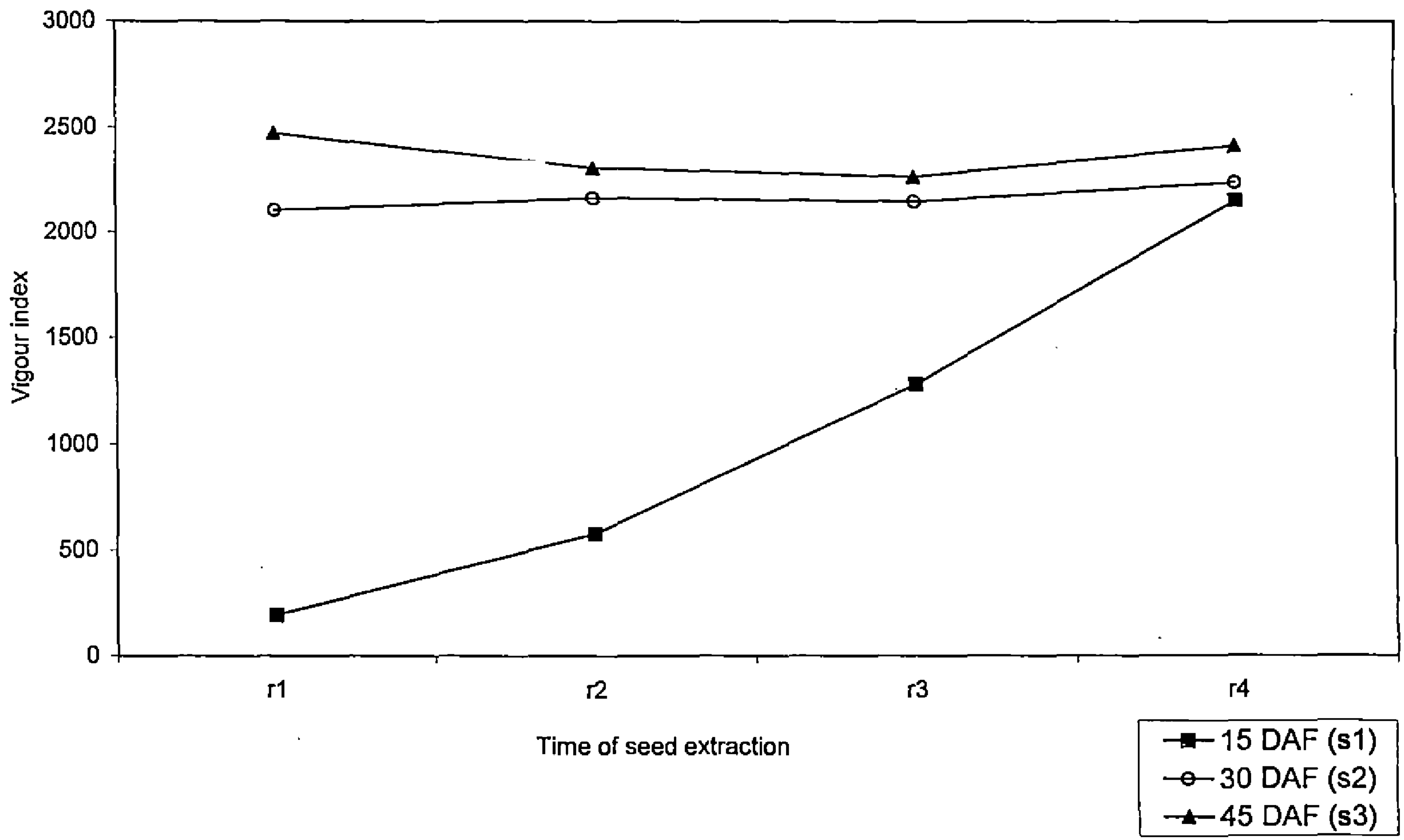


Fig. 13 Effect of time of seed extraction on vigour index at different stages of harvest



DAF was kept as such for nine days before extraction under ambient conditions. But when the fruits were harvested at 30 and 45 DAF seed quality parameters showed slight improvement by keeping the fruits intact for few days before seed extraction eventhough it was not significant (Tables 17 and 19). The effect of time of seed extraction on speed of germination and vigour index at different stages of harvest is presented in figures 12 and 13 respectively. The improvement in seed quality parameters by post harvest storage of fruits were in agreement with the findings of Cochran (1943), Young (1949), Quagliotti *et al.* (1981), Araujo *et al.* (1982), Nagy (1987), Buriev (1987) and Krishnaswamy (1991). This improvement in seed quality may be due to the continuous development and maturation of seeds within the fruits even after they are separated from the vine. This is indicated by the higher seed weight per fruit and 1000 seed weight, because of the accumulation of reserve food materials, proper development of embryo and also because of the reduced moisture content of the seed which reflects further on other quality parameters.

To get maximum yield of good quality seeds fruits can be harvested at 30 DAF. Seed quality was improved by the storage of fruits prior to seed extraction. Even when the fruits were harvested at an immature stage of 15 DAF, good quality seeds can be obtained by storing the fruits for nine days.

SUMMARY

6. SUMMARY

An experiment was conducted at the College of Agriculture, Vellayani to study the influence of number of vegetable harvests and growth regulator on seed yield and quality in cucumber. The treatments consisted of three levels of vegetable harvest (zero, one and two) and four different concentrations of ethephon (zero, 100, 200 and 300 ppm). Ethephon which is chemically 2-chloroethyl phosphonic acid (38 per cent) was used for the experiment. The experiment was laid out in strip plot design with the number of vegetable harvests on horizontal strips and the levels of growth regulator in vertical strips and replicated three times. The salient findings of the study are summarised below.

Increase in the number of vegetable harvests caused a significant increase in the length of vine, number of branches and LAI. Maximum length of vine, number of branches and LAI were recorded for two vegetable harvests. Increase in the concentration of growth regulator caused a proportionate reduction in vine length with the longest in zero ppm and shortest in 300 ppm. Growth regulator had no significant influence on number of branches. LAI showed a significant increase with growth regulator, the highest in 300 ppm and lowest in zero ppm. The LAI under zero ppm and 100 ppm were on par.

Number and weight of green fruits per plant and green fruit yield were increased significantly by increase in number of vegetable harvests from zero to two. Number and weight of green fruits per plant and green fruit yield

(8552.29 kg ha^{-1}) were maximum for two vegetable harvests. Application of growth regulator also caused significant influence on the yield of green fruits showing maximum performance with 200 ppm of ethephon (7197.93 kg ha^{-1}) which was on par with 300 ppm.

Weight of mature fruits per plant and mature fruit yield showed a significant reduction with increase in the number of vegetable harvests. Maximum mature fruit yield per plant and per hectare were recorded when the plants were left without green fruit picking (6786.48 kg ha^{-1}) and the lowest in two vegetable harvest. Growth regulator caused a significant increase in mature fruit yield recording highest at 200 ppm (6234.81 kg ha^{-1}) and the lowest at zero ppm.

Total number of fruits harvested per plant was influenced by number of harvests and growth regulator. Two vegetable harvest recorded highest number of fruits. Among the levels of growth regulator 200 ppm gave the highest number of fruits at all levels of harvest.

Number of harvests had no significant influence on length and girth of green and mature fruits. Application of growth regulator caused a significant reduction in girth of green fruits.

Shelf life of green fruit was not influenced by number of harvests and growth regulator.

Number of seeds per fruit decreased with increase in number of harvests. Maximum number of seeds per fruit was produced under zero vegetable harvest. Application of growth regulator increased the seed number producing highest under 200 ppm.

Fruit to seed ratio was increased significantly with increase in the number of harvests. Highest fruit to seed ratio was recorded under two vegetable harvest which was on par with that under one harvest. The influence of growth regulator was not significant.

Weight of seeds per fruit, seed yield per plant and per hectare were also influenced by the number of vegetable harvests and growth regulator. Increase in number of vegetable harvests caused a decrease in seed yield. Maximum seed yield per fruit, per plant and per hectare were recorded from the plant which were left as such without green fruit picking (152.84 kg ha^{-1}). Among the levels of ethephon, maximum seed yield (166.29 kg ha^{-1}) was produced under 200 ppm ethephon which was on par with that at 300 ppm. Under all levels of harvest maximum seed yield was produced with 200 ppm ethephon.

1000 seed weight was not influenced by number of harvests. Growth regulator had significant influence on 1000 seed weight. Maximum 1000 seed weight was recorded at 100 ppm ethephon.

Seed viability per cent, germination per cent and speed of germination were not affected by number of harvests and growth regulator.

Seedling characters such as seedling shoot length, root length, VI and seedling dry weight were also not influenced by number of harvests and levels of ethephon.

Economic analysis of the treatments revealed that number of harvests and growth regulator influenced the net returns and B : C ratio. Net return and B : C ratio increased with increase in number of vegetable harvests.

Highest net return and B : C ratio were obtained under two vegetable harvest (Rs. 58731.52 ha^{-1} and 2.2 respectively). Among the levels of growth regulator 200 ppm ethephon gave maximum net returns and B : C ratio (Rs. 51567.72 ha^{-1} and 1.84 respectively). At all levels of harvest net return was maximum at 200 ppm ethephon and the most economic combination was found to be two vegetable harvests with 200 ppm of ethephon.

To get maximum returns seed production can be combined with two vegetable harvests. Eventhough the number of harvests reduces seed yield seed quality was not affected. So reasonably good yield of quality seed along with some vegetables is obtained. 200 ppm of ethephon gave the highest fruit and seed yield and had no effect on seed quality except for 1000 seed weight.

A second experiment was also conducted to study the influence of stages of harvesting and time of seed extraction on seed yield and quality in cucumber. The experiment was laid out in factorial randomised block design with three replications. The treatments consisted of three stages of harvest (15 DAF, 30 DAF and 45 DAF) and four different time of seed extraction (extraction of seed on the same day of harvest, three days after harvest, six days after harvest and nine days after harvest).

Fruit to seed ratio increased with the advancement of time of harvest. Maximum fruit to seed ratio was observed when harvesting was done at 30 days after flowering which was on par with that harvested at 45 days. Among the time of seed extraction maximum fruit to seed ratio was obtained when the seeds were extracted at six days after harvest.

Number of seeds per fruit was not influenced by stages of harvest and time of seed extraction but the weight of seeds per fruit showed significant influence. Maximum seed weight was recorded when the fruits were harvested at 30 days after flowering. Seed weight per fruit recorded highest value when extracted nine days after harvest. When the fruits were harvested at 15 and 30 days after flowering, maximum seed weight was observed when fruits were stored for nine days before seed extraction. But at 45 days after flowering seed weight was highest when extracted on the same day of harvest.

1000 seed weight increased with the increase in time of harvest and extraction time. Maximum 1000 seed weight was observed in fruits harvested at 30 days after flowering. Among the time of seed extraction maximum 1000 seed weight was recorded when the fruits were stored for nine days.

Seed viability, germination per cent and speed of germination increased steadily with advancement of days of harvest recording maximum values at 45 days after flowering. Among the time of seed extraction, the seeds extracted from fruits stored nine days after harvest performed better in terms of seed viability and germination per cent. When the fruits were harvested at 15 days after flowering and extracted on the same day of harvest, seed viability and germination were lowest which increased sharply with the storage of fruits for nine days before seed extraction reaching almost equal to the seeds from the fruits harvested at 30 and 45 days after flowering. When harvest was done at 30 and 45 days after flowering, storage of intact fruit before seed extraction had no influence on seed viability and germination per cent.

Seedling shoot length and root length were highest for the seeds harvested at 45 DAF. Among the time of seed extraction, maximum shoot and root length were observed when seed extraction was done after storing the fruits for nine days. Shoot length of the seedlings produced from seeds collected at 15 days after flowering and extracted on the same day of harvest was lowest which showed a spectacular increase when seed extraction was done nine days after harvest. But at 30 and 45 days after flowering seedling shoot length was not influenced by extraction time.

Vigour index and seedling dry weight increased with increase in the time of harvest recording maximum at 45 DAF. Among the time of seed extraction highest vigour index was recorded when the seeds were extracted nine days after harvest whereas seedling dry weight was maximum at six days after harvest. The interaction effect showed that at 15 days after flowering, there was a sharp increase in vigour index and seedling dry weight by increasing the time of seed extraction with maximum values when stored for nine days.

Fruits can be harvested at 30 days after flowering to get seeds with high quality. Storage of fruits prior to seed extraction also influence the seed quality. The quality of seeds from fruits harvested at 15 days after flowering increased by storage of fruits. But when harvesting was done at 30 and 45 days after flowering storage of fruits had no influence on seed quality.

Future line of work

1. The same experiment can be repeated to confirm the trend of results obtained in the present experiment.
2. Field performance of the seeds obtained from the experiment can be evaluated.
3. Experiment can be conducted to study the effect of repeated application of growth regulator at different stages of crop growth on seed yield and quality.
4. The combined effect of different concentrations of growth regulators with varying doses of plant nutrients on fruit and seed yield and quality can be evaluated.

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*Original not seen

APPENDIX

APPENDIX – I

Weather data for the crop period – weekly averages (November 1999 – February 2000)

Standard week	Max. temp. (^0C)	Min. temp. (^0C)	Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
44	29.5	23.3	82.6	0.14	3.10
45	30.1	23.1	79.4	0.83	2.80
46	30.3	22.9	82.4	15.46	2.98
47	29.7	23.4	81.7	2.40	2.40
48	29.6	22.7	83.6	4.46	2.40
49	30.1	22.9	80.5	0.14	2.77
50	30.2	23.4	81.8	7.40	2.88
51	30.2	22.8	80.0	9.24	2.69
52	29.1	23.4	84.7	6.51	2.00
1	31.8	21.6	79.5	-	3.07
2	30.0	22.9	80.7	-	2.41
3	30.6	20.8	76.7	0.06	3.24
4	30.8	20.6	76.7	-	3.13
5	31.2	22.5	77.7	1.4	3.21

EFFECT OF HARVESTING AND GROWTH REGULATOR ON SEED YIELD, QUALITY AND VIGOUR IN CUCUMBER (*Cucumis sativus* L.)

By

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ABSTRACT OF THE THESIS
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ABSTRACT

A field experiment was conducted at the College of Agriculture, Vellayani to study the influence of harvest and growth regulator on seed yield, quality and vigour and also to standardise the physiological stage of maturity in cucumber.

Growth characters such as length of vine, number of branches and leaf area index were significantly influenced by vegetable harvests and these characters increased with increase in number of vegetable harvests. The bearing capacity of the plant is improved by frequent picking of green fruits, but the mature fruit yield and seed yield were significantly reduced. Highest seed yield was obtained when the plants were left for seed collection without green fruit picking. Seed quality is not influenced by number of harvests. But when the economics is considered highest net return and B : C ratio were obtained for two vegetable harvest. So to obtain maximum returns we can combine seed production along with two vegetable harvests which gives some vegetable yield and reasonably good yield of quality seeds.

Growth regulator caused reduction in vine length. Number of branches was not influenced by growth regulator. But LAI showed a significant increase. Growth regulator caused significant increase in green and mature fruit yields and seed yield. Fruit yield, seed yield and net return were highest at 200 ppm of ethephon. Seed quality was not affected by the application of growth regulator except for 1000 seed weight.

Seed quality is significantly influenced by stages of harvest. Weight of seeds per fruit and quality were highest for seeds when fruits were harvested 45 days after flowering which was on par with that at 30 days after flowering. Storage of fruits intact before seed extraction also had significant effect on increasing seed quality. Seed quality was highest when the seeds were extracted after storing the fruits for nine days. Even when the fruits were harvested at immature stage (15 days after flowering) the seed weight per fruit and seed quality parameters can be increased by storing the fruits intact before seed extraction for nine days. But when the fruits were harvested at 30 and 45 days after flowering there was not much variation in seed quality by post harvest storage of fruit before seed extraction.