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SEED INVIGORATION STUDIES IN ASH GOURD (*Benincasa hispida* Thunb.)

By

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THESIS

submitted in partial fulfilment of the requirement for the degree of

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Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that this thesis entitled **"Seed invigoration studies in ash gourd (*Benincasa hispida* Thunb.)"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara

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CERTIFICATE

Certified that this thesis, entitled **"Seed invigoration studies in ash gourd (*Benincasa hispida* Thunb.)"** is a record of research work done independently by **Miss.Jyothilakshmi Unnikrishnan.,** 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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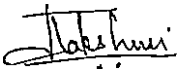

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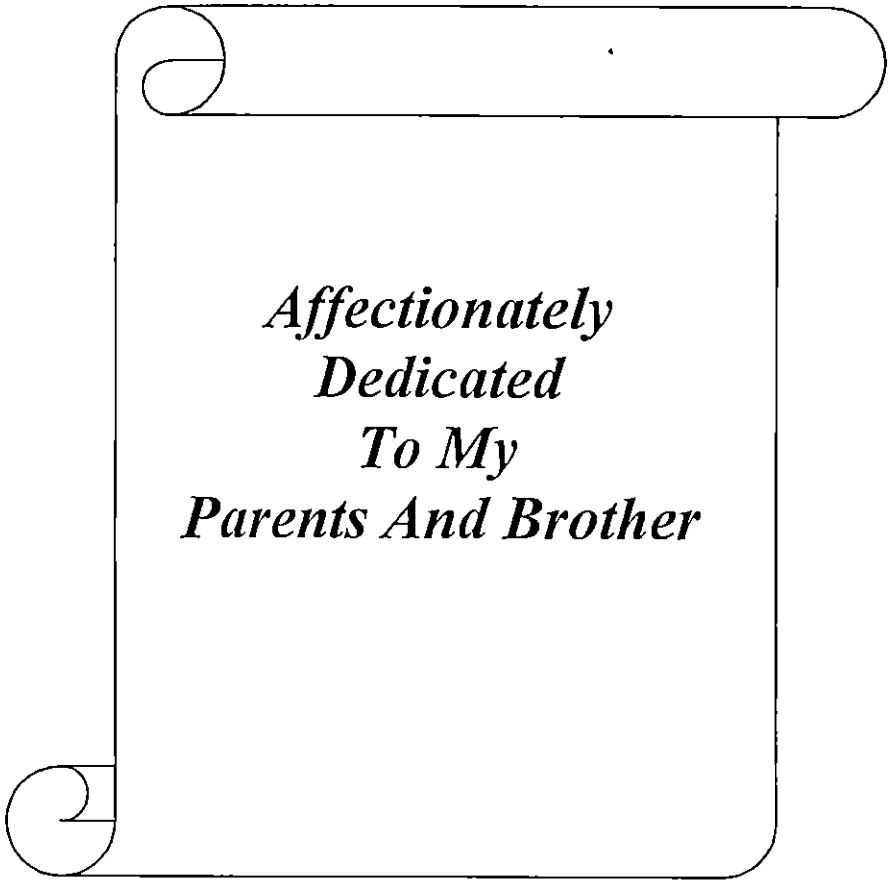
Affectionately
Dedicated
To My
Parents And Brother

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Introduction

1. INTRODUCTION

The term seed dormancy has been used to describe two inactive conditions: one resulting from unfavourable environmental conditions and other due to internally imposed germination blocks. It is necessary to distinguish seed dormancy resulting from an unfavourable environment from that due to the presence of inherent blocks.

Among the different cucurbitaceous crops, various forms and lengths of dormancy have been reported in cucumber, bitter gourd and muskmelon. The dormancy in cucurbits lasts for 6-12 months and is due to the presence of multi layered perisperm- endosperm envelop which contribute to impermeability to gas and water uptake (Brown, 1940). Some cucurbits exhibit dormancy in freshly harvested seeds, which can be broken by a month or more of after ripening (Robinson and Walters, 1997). Seed maturation in cucurbits usually continues until they are extracted from the fruits. After ripening is a pre- requisite for full maturation of seeds in the cucurbits where seed maturation is incomplete by the time we harvest the crop.

Ash gourd has become very popular in Kerala due to easiness in culture, wide adaptability, comparatively low susceptibility to serious pests and diseases and suitability to grow in all seasons. The fruits are used in culinary preparations confectionaries and also used for various medicinal preparations.

The fresh ash gourd seeds could not be used by the farmers till four months since they do not show the required germination per cent. Breakdown of dormancy in natural course is gradual during storage. The fruits are harvested at full maturity and stored for seed extraction in the farmers holding, also the fruits for seed purpose is hanged using rope and protected from cuts and breakages till next sowing. But more space is needed for keeping large quantity of fruits and this

technique is not economically feasible and very often there will be rat menace during storage.

Invigoration is defined as any pre-sowing management practices adopted to break dormancy, improve seed quality and to boost productivity of crops. By standardizing the invigoration technique that could break the dormancy in seeds of freshly harvested fruits it would be possible to use the seeds immediately after extraction by the farmers without waiting for the natural process of dormancy breaking.

Unless the storage potential of invigorated seeds is studied , it would not be possible to know whether the initial influence is retained even after storage. If the treated seeds could be stored without any deleterious effect, such treated seeds can be directly supplied to farmers for cultivation.

Farmers are using seeds of previous "Varshakumbalam" and "Venalkumbalam" for better performance during the successive rainy season and summer season respectively. The scientific validity of such traditional methods is not yet been tested. A comparison between such invigoration treatments and these traditional farmers practices would be always beneficial before giving a recommendation. Similarly it is always essential to test the laboratory-identified treatments in the field to get confirmatory results.

Hence the present investigation was taken up at the Department of Olericulture, College of Horticulture, Vellanikkara during 2002-2004 with the following objectives:

To find out the effect of invigoration to break seed dormancy of ash gourd

To find out the storage potential of invigorated seeds and

To compare the field performance of invigorated seeds with traditional practices.

Review of Literature

2. REVIEW OF LITERATURE

The relevant available literature on seed dormancy in vegetables, dormancy breaking treatments, seed invigoration studies, storage potential and field performance of invigorated seeds are reviewed here under.

Seed is an incubator with an immune covering (the seed coat) and a nutritive insurance (the endosperm) for the continuum of the species (the embryo). The eventual function of the surviving seed is its germination, followed by the growth of the embryo to give a mature plant. For germination to occur, seeds require moisture, a suitable temperature, and in most cases an aerobic atmosphere. If one or more of these requirements is not met, germination will fail to occur, and in this condition the seeds may be regarded as being in a state of imposed dormancy.

Harrington and Knowles (1939) have defined seed dormancy or after ripening as one, which refers to the rest period of a mature seed in the presence of conditions favoring germination and no apparent physical impediment to germination.

Roberts (1972) defined dormancy as a state in which a viable seed fails to germinate when placed in conditions normally considered to be adequate for germination, i.e., when provided with suitable temperature, adequate moisture and oxygen.

2.1 DORMANCY IN VEGETABLES- CAUSES, TYPES

Stier (1938) stated that the seed coat is responsible for restricting the oxygen supply to the embryos of potato.

The nucellar membrane is reported to contribute to impermeability to gases in *Cucurbita pepo* (Brown, 1940) and *Cucumis sativus* (Ali *et al.*, 1991) and thus causing dormancy.

Shifriss and George (1965) reported dormancy in cucumber (*Cucumis sativus*) c.v. Baroda, for a period of 6 to 12 months.

Gutterman, (1973) found that in *Lactuca sativa*, germinability was promoted by short day regimes, while dormancy increased with day length.

Ednapsis and Ng (1986) reported seed coat imposed dormancy in musk melon, where the seed coat inhibit germination by decreasing oxygen uptake.

Krishnaswamy (1990) reported that fresh seeds of high yielding brinjal variety 'Annamalai' exhibit dormancy.

Quagliotti *et al.* (1994) reported that okra seeds exhibit dormancy resulting from a hard, water resistant seed coat and a chalazal plug, causing very slow water uptake.

Suryawanshi *et al.* (1996) revealed that the impermeability of nucellar membrane to oxygen and water intake contributed to the dormancy in *Cucumis sativus* c.v. Himangi to the extent of 66 per cent and was maintained upto 49 days.

Ladeira (1997) reported that freshly collected seeds of nightshade (*Solanum americanum*) exhibited dormancy at a temperature of 25 ^{0} C.

Katiyar *et al.* (1998) found that freshly harvested seeds of *bittergourd (Momordica charantia* L.) from rainy season crop of variety Kalyanpur baramasi did not germinate in Northern India due to inherent seed dormancy.

Lan-fu-sheng *et al.*(1998) observed that sea kale (*Crambe maritima*) seeds germinate very slowly with a low germination percentage due to seed dormancy and slow water imbibition as a result of a thick and hard seed integument.

Pandita *et al.*(1999) found that hard seededness is a serious problem in the multicut leafy vegetable *Trigonella corniculata*, resulting into dormancy

Welbaum (1999) reported primary dormancy in *Cucumis melo*.

Sreenivasalu *et al.* (2000) revealed secondary dormancy in cucumber cv. Poinsett- 76 as a result of intracellular membrane of the embryonic axis and cotyledons.

Yogeesha *et al.* (2002) observed 96 per cent dormancy in fresh seeds of brinjal variety Arka Neelkant due to the presence of ABA.

Ganar (2003) revealed that seeds extracted from fresh ashgourd fruits exhibited dormancy and showed a very low germination of 5 per cent during kharif season and 10 per cent during spring summer.

2.2 DORMANCY BREAKING TREATMENTS

2.2.1 Use of Growth Regulators

Beneficial effects of GA_3 in breaking the dormancy and increasing the vigour of pea seedlings were reported by Arney and Mancinelli (1966) and Mayer and Shain (1974).

Srivastava and Sachan (1971) observed that seed soaked with GA_3 enhanced the emergence of okra seedlings in the nursery.

Vanangamudi *et al.* (1988) reported that in bellary onion c.v. Rampur local, soaking seeds with GA_3, 100 ppm for 3 hours was found to break the dormancy, there by improved the germinability, vigour and the emergence of the seedling in the nursery.

According to Suryawanshi et *al.* (1996) the dormancy in *Cucumis sativus* c.v. Himangi was overcome by treating the seeds with 100 ppm GA_3.

Katiyar *et al.* (1998) reported that GA_3 (150 ppm) and hot water (40 ^{0}C for two minutes) treatment were effective in improving germination and overcoming seed dormancy in rainy season crop of bittergourd variety Kalyanpur baramasi.

According to Sujatha and Kalavathi (2002) the dormancy in coriander seeds, could be broken by different methods. The highest germination (84%) could be obtained by leaching in running water for 16 hours, followed by soaking in GA_3 for 16 hours, or in KNO_3 (0.5%) for 24 hours.

Yogeesha *et al.* (2002) stated that dormancy in fresh seed of brinjal variety Arka Neelkant could be overcome by treating with GA_3 200 ppm for 2 hours.

2.2.2. Other Methods for Breaking Dormancy

Singh and Singh (1969) reported that dormancy in bitter gourd could be broken by acid scarification of seeds, with dilute H_2SO_4, HNO_3 or HCl for 30-60 minutes.

Thomas (1990) explained the dormancy breaking effect of red light on celery seeds when incubated at high temperature and concluded that it involves gibberllic acid biosynthesis for overcoming dormancy.

Ali *et al.* (1991) found that in cucumber c.v. Baroda, dormancy was broken when seeds were subjected to puncturing, removal or cutting the inner integument.

Weston *et al.* (1992) observed that after ripening increases the growth potential of embryo by allowing radicle penetration of the seed coat, which presents a significant physical barrier in dormant seeds of cucumber.

Malarkodi *et al.* (2002) reported that treating cowpea seeds with KH_2PO_4 or Na H_2PO_4 at 0.5 per cent improved germination and seedling growth.

2.3 SEED INVIGORATION STUDIES ON GERMINATION

Pisani (1959), Chatterjee (1960) and Bhatt (1963) have demonstrated increased germination and seedling growth in respect of carrot and brinjal by treating seeds with various growth regulators.

Choudhury and Singh (1960) treated the seeds of tomato with four plant regulators viz. β-naphthoxyacetic acid (NOA), para-chlorophenoxyacetic acid (CIPA), 2, 4- dichlorophenoxy acetic acid (2,4-D) and GA_3 at 5,10,15 and 20 ppm concentrations for 24 hours. Maximum germination was obtained by 2,4-D at lower concentration while at higher concentration it was found to be toxic. NOA at 50 ppm, GA_3at 20 ppm and CIPA at 40 ppm also gave better germination when compared to control.

According to Voldin (1960) GA stimulated seed germination in egg plant

Arnoux (1962) reported enhanced germination in cucumber seeds by treatment with methyoxy ethyl mercuric silicate, thiram, copper oxinate or phallan.

Sadawarte and Gupta (1968) observed increased percentage of germination in brinjal seeds by pre-sowing soaking with IAA and NAA each at 5 and 10 ppm.

The beneficial effects of GA and NAA on okra seed germination were reported by Srivastava and Singh(1968).

Pal *et al.* (1970) studied the effect of GA, IAA and B-NOA as a pre sowing seed treatment on germination of okra. Amongst these GA 10 ppm and IAA 100 ppm concentration gave 100 per cent germination.

According to Abdul- Baki and Anderson (1972) the differential germinability of hydration- dehydration treated and control seed has been related to dehydrogenase activity, membrane functions and lipid peroxidation.

Muminov (1973) stated that soaking of melon seeds in water for 24- 36 hours enhanced germination.

Rao and Rao (1973) found that the germination of Pusa long variety of bhendi was significantly reduced by treatments with 2,4,5-T 30 ppm, ClPA 60 ppm and 2,4-D at 7.5, 10 and 15 ppm. They stated that it was due to the inhibitory effects of the phenoxy compunds on seed germination.

According to Singh *et al.* (1973) seed soaking for 24 hours in GA, IBA, NAA, 24-D at 25-100 ppm and distilled water increased the per cent germination in bottle gourd, bitter gourd, watermelon and okra.

Nagy (1974) found that seed soaking in water at 30 ^{0}C for 4 hours is essential for watermelon as it increased the germination percentage.

According to Sachs (1977) seed priming using 2% or 3% KNO_3 for 6 days improves germination though NH_4NO_3, $NaNO_3$, $Ca(NO_3)_2$ and KCl had similar effect on field emergence under low temperature in winter grown watermelon.

Suryanarayana and Arifuddin (1980) investigated the effect of pre-treatment in okra seed with GA at 50, 100 and 150 ppm and NAA at 10, 20 and 40 ppm. Treatment with GA at 150 ppm concentration resulted in the highest percentage of seed germination.

Solanki and Joshi (1984) invigorated the seeds of onion (*Allium cepa* L.) and carrot (*Daucus carota* L.) using KH_2PO_4, KNO_3 and GA_3 at different concentrations along with hot water treatment. The maximum germination was recorded in case of onion seeds soaked in KNO_3 (3%) solution, where as hot water soaking for 12 hours resulted in maximum germination of carrot.

Dey and Mukherjee(1986) revealed increased activity of dehydrogenase, peroxidase and lowering of free fatty acids formation, lipase activity and lipid per oxidation as the contributing factors for higher germinability of treated seeds.

Singhvi and Chaturvedi (1990) reported that presoaking in distilled water for 12 hours or solutions containing 10, 25 or 50mg of GA_3 per litre or 10, 25 or 50 mg of morphactin per litre promoted radicle length and hypocotyl extension in radish.

Renugadevi (1992) found that treatment with KNO_3 1 per cent recorded a significant increase in seed germination, speed of germination, dry matter production and vigour index of seedling in ash gourd.

Latha (1992) reported low germination percentage in CM 214 (*Cucurbita moschata*) due to the presence of hard seed coat. Various seed treatments like

mechanical scarification, hot water treatment, dipping in GA_3 etc did not improve the germination percentage considerably. But when the seed coat was removed, the germination percentage increased upto 71.4 per cent.

Rengudevi and Selvaraj (1994) reported that for achieving hundred per cent viability and enhanced vigour in bittergourd cv. CO.1, pre-treatment of seeds with 1% KNO_3 is beneficial.

Manoharan (1999) observed remarkable improvement in germination percentage by osmo priming of chilli seeds with chemicals like sodium chloride during the tenth month of storage.

Singh *et al.* (1999) revealed that osmo conditioning of seeds of muskmelon c.v. PunjabHybrid and Punjab Sunehri with PEG-6000 (-8 bars) and KNO_3 (0.35 M) containing 0.2% thiram as fungicide at 15^0C for 3,5 and 7 days increased per cent germination, speed of germination and vigour. KNO_3 recorded more pronounced effect in all the above mentioned parameters.

Bhuyar *et al.* (2000) studied the effect of growth regulators like GA_3, thiourea and NAA on seed germination in spine gourd (*Momordica dioica* Roxb). Amongst the three growth regulators GA_3 200 ppm was superior to all the other treatments with respect to early germination per cent, shoot and root growth.

Osmoconditioning with PEG (-8 bars) containing 2% thiram for 3 days recorded good germination and higher speed of germination (Singh *et al.*, 2001) in muskmelon cv. Pb. Sunehri

Germination per cent of onion variety Kalyanpur Red Round was improved significantly by seed treatment with GA_3 100 ppm and NAA 10 ppm (Tewari *et al.*,2001).

Menaka *et al.* (2002) found that brinjal seeds when exposed to 12 hours of white light followed by 12 hours of red light, registered maximum germination percentage, root length, shoot length and vigour index.

Pandita and Nagarajan (2002) indicated that both osmopriming (-1.0M Pa PEG-6000 and -1.0M Pa Mannitol) and the simple technique of wrapping seeds in wet muslin cloth for 48 hrs at 25°C improved field emergence and seedling quality in bittergourd under low temperature conditions.

Ganar (2003) reported that seed invigoration treatment with 2% KNO_3 for 2 days and PEG (6000) 30% for 2 days improved field emergence in ashgourd during adverse climatic conditions of spring - summer seasons.

2.4 STORABILITY OF INVIGORATED SEEDS

Vicek (1963) reported that pre- sowing soaking of seeds in water for 48 hours and storing for one to five days at 6°C increased the yield of tomato by 19.04 per cent.

Basu *et al.* (1975) reported the usefulness of seed storage correction treatments in controlling the seed deterioration in wheat, jute, rice, sunflower, pulses and vegetables during storage. They also suggested second time invigoration of seeds for prolonging the viability of the seeds.

Basu *et al.* (1979) reported that dry permeation of potassium iodide (10^{-4} M), p-hydroxy benzoic acid (10^{-4}M) and tannic acid by employing acetone as infusing solvent effectively controlled the deterioration in the acceleratedly aged seeds of lettuce.

Rudrapal and Basu (1980) stated that iodine treatment to 18 months old mungbean seeds greatly minimised the seed deterioration in accelerated ageing conditions.

Suryanarayana and Arifuddin (1980) treated the seeds of okra variety Pusa Sawani with GA and NAA at different concentrations and stored for a period of 30 days. Results revealed that storage of treated seeds for 15 to 30 days did not have much deleterious effect on growth and yield of plants.

Woodstock *et al.* (1983) found that treatments of onion, pepper and parsley seeds with several concentrations of tocopherol and butylated hydroxytoluene improved storability in some storage conditions but increased deterioration in others.

According to Metha and Ramkrishnan (1986) hydration treatments with sodium phosphate (dibasic) for 3 hours and drying back to its original weight slowed down the rate of deterioration of both large and small seeds of CO-1 chilli under 12 months of storage.

Gayathri and Kalappa (2002) invigorated the seed lots of tomato hybrid, Akash differing in germination percentage using different methods. Invigoration with selected chemicals, humidification (24 hours at 95% RH) and hydration-dehydration for 6 hours at 1:1 (wt/vol.) seed to water ratio followed by shade drying (43 hours) were tried and stored at room temperature (25^0C) for four months period. Seed invigoration with 1% KNO_3 showed enhanced performance even after storage.

2.5 POST HARVEST RIPENING TO IMPROVE SEED QUALITY

Young (1949) recorded an increased germination of 98.4 per cent in butternut squash after four months of storage.

Petrov and Dojkov (1970) reported that storage of mature brinjal fruits for 3,5 and 7 days increased the percentage germination of seeds but did not affect the absolute seed weight.

Petrov *et al.* (1981) observed the development of brinjal seeds even after separation of fruits from mother plants, on account of continuous supply of food reserves from fruit to seed.

Quagliotti *et al.* (1981) reported the essentiality of post harvest ripening in chilli seeds for increased percentage of fruits containing viable seeds.

Araujo *et al.* (1982) reported increased seed germination with increasing fruit age and storage length in cucurbits.

Nagy (1987) reported that post harvest storage for two weeks of *Cucurbita pepo*, fruits resulted in improved germination.

According to Buriev (1987) best quality seeds were obtained from 40 day old cucumber fruits after ripened for 10 or 15 days.

Krishnaswamy and Pandian (1991) stated that in bitter gourd, seeds continue to mature in fruits which are harvested before ripening and stored under ambient conditions.

Gowda and Ramegowd (1996) reported that the fruit of cucumber, post harvest ripened for 15 days, gave highest seed quality in terms of germination, field emergence and vigour.

Kannath (1996) stated that seeds extracted from fresh fruits of ashgourd recorded very low germination and vigour. According to him the fruits should be stored for a period of three months to get satisfactory germination.

Manju (1997) collected different indigenous practices followed by farmers of Thrissur district. The fruits of ashgourd are hung using rope for seed purpose and just before sowing, the fruit is broken down and seeds collected and sown directly in the field.

Robinson and Walters (1997) stated that the dormancy in freshly harvested seeds of cucurbits can be broken by a month or more of after ripening.

Mini *et al.* (2002) observed that seeds of capsicum accessions exhibited an after ripening requirement for a period of 3-4 weeks that could be obtained by a period of warm dry storage. After ripening for five weeks period resulted in poor seedling performance.

According to Sureshbabu *et al.* (2003) postharvest ripening up to six days was found to be beneficial in obtaining higher quality brinjal seeds.

2.6 SEED INVIGORATION STUDIES ON FIELD PERFORMANCE

2.6.1 Effect of Seed Invigoration on Vegetative and Reproductive Stages.

Choudhury and Singh (1960) noticed that in tomato, seed treatment with gibberellin at 10 and 15 ppm gave the highest shoot elongation closely followed by 5 and 20 ppm.

Adulka and Verma, (1965) reported early flowering and increased yield in tomato due to application of GA. Similar results were reported in brinjal (Sadawarte and Gupta, 1968) and okra (Nandpuri *et al.*, 1969)

GA_3 25 ppm has been reported to increase the number of flowers in *Pisum sativum* (Manohar *et al.*, 1966)

The number of functioning leaves per plant was significantly higher when the seeds of brinjal were treated with GA 40 ppm (Sadawarte and Gupta, 1968).

Das and Prusty (1969) studied the effect of application of GA, CCC and MH for 24 hours, each at 10, 50 and 100 ppm in brinjal seeds. It was revealed that GA 10 ppm caused the earliest anthesis as compared to all other treatments.

Even (1970) found that seeds soaked in 50 ppm GA induced early flowering and early fruit maturity in egg plant.

Pal *et al.* (1970) observed that seed treatment with NOA at 400 ppm gave maximum number of flowers per plant followed by GA at 400 ppm.

However in contrary to this, Rao and Rao (1973) reported that growth regulators like 2,4,5-T. CIPA, IPA, b-NOA and 2,4-D were found to delay the flowering significantly in bhendi (*Abelmoschus esculentus* L. Moench).

Suryanarayanana and Arifuddin (1980) reported that seeds of okra variety Pusa Sawani when treated with GA 150 ppm resulted in tallest plants and maximum number of leaves per plant.

2.6.2 Effect of Seed Invigoration on Yield

Choudhury and Singh (1960) reported higher yield in tomato by treating seeds with NOA, 2,4-D, CIPA and GA_3 for 24 hours prior to sowing.

According to Singh and Dohare (1964) highest yield was obtained in radish at lower concentration of NAA (10, 40 and 80 ppm) while the yield was reduced at higher concentration.

Sadawarte and Gupta (1968) reported that the yield of brinjal,variety Pusa Purple Long could be almost doubled by soaking the seeds in IAA 50 ppm or GA 40 ppm solution for 24 h. Fruits from plants treated with NOA and p-CPA treatments were greater in weight and had less number of seeds.

Pal *et al.* (1970) informed that among GA_3 treatments at various concentrations, GA 400 ppm gave the highest yield in okra. Maximum number of fruits were also obtained.

Pre- sowing soaking in one per cent potassium nitrate or 1.5 per cent potassium phosphate for 3 h and periodical wetting over 69 h and drying to 10-11 per cent moisture content gave better plant stand and yield/ unit area in tomato and capsicum (Dimov *et al.*, 1978).

Presowing seed treatment gave better seedling performance, field establishment and increased yield in *Beta vulgaris* (Basu and Dhar, 1979) and tomato (Mitra and Basu, 1979).

Patil and Ballal (1980) found that seed treatment with IAA 40 ppm, GA 40 and 80 ppm and IAA 80 ppm along with foliar spray of NAA 50 ppm produced significantly more yield per plot than seed treatment alone in green chilli variety NP-46A.

Singh *et al.* (2002) stated that vegetable quality, yield, seed yield and quality are directly dependant on the quality of seedlings raised

Materials and Methods

MATERIALS AND METHODS

The present investigation "Seed invigoration studies in ash gourd (*Benincasa hispida* Thunb.)" was carried out at the Department of Olericulture, College of Horticulture, Vellanikkara during 2002-2004.

The experimental site was located at an altitude of 22.5m above M.S.L, between 10^0 32' N latitude and 75^0 16' longitude. The location experiences a warm humid tropical climate. The soil for the experimental site comes under the textural class of sandy clay loam and is acidic in reaction. The average monthly values of the meteorological parameters like rainfall, maximum and minimum temperatures and relative humidity are collected from the observatory attached to College of Horticulture and are presented in Appendix-I

The study consisted of three experiments.

1. Seed invigoration to break dormancy
2. Storage potential of invigorated seeds
3. Field performance of invigorated seeds

The materials used and the methods adopted for the study are briefly described below.

3.1 SEED INVIGORATION TO BREAK DORMANCY

Ash gourd variety KAU Local was grown in the research fields of Department of Olericulture during summer season (Feb-May), 2003, adopting the recommended cultural operations (KAU, 2003). Fully matured uniform fruits were harvested 120 days after sowing and seeds extracted manually immediately after harvest.

Plate 1. Field view of experimental plot

The extracted seeds were dried to 8% moisture, cleaned and stored in 700 gauge polythene cover at ordinary room temperature. Sample seeds were drawn and evaluated at monthly intervals under laboratory conditions after giving the following different treatments, starting from the month of storage upto six months.

T_1- 5N H_2SO_4 for 10 minutes
T_2- 5N HCl for 30 minutes
T_3- 5N HNO_3 for 20 minutes
T_4- Water soaking for 8 hours
T_5- Hot water (40^0C) soaking for 5 minutes
T_6- GA_3 (25 ppm) for 24 hours
T_7- GA_3 (50 ppm) for 24 hours
T_8- GA_3 (100 ppm) for 12 hours
T_9- NAA (25 ppm) for 24 hours
T_{10}- NAA (50 ppm) for 24 hours
T_{11}- NAA (100 ppm) for 12 hours
T_{12}- 1 per cent KNO_3 for 12 hours
T_{13}- Control

Number of treatments - 13
Number of replications - 3

The following parameters were recorded in each month.

3.1.1 Intensity of Dormancy

A total number of 3 x 50 seeds drawn at random from stored polythene cover and were placed in sterilized sand medium for germination under ambient conditions. The seedlings were watered daily. The number of non germinated seeds in the test at five days after sowing (NGS_5) and at ten days after sowing (NG S_{10}) was calculated from the number of germinated seeds and the mean

number of non germinated seeds to the total number sown was expressed as intensity of dormancy in percentage. (Swain *et. al.*, 2001).

3.1.2 Days to achieve 60 per cent germination

The number of days taken from the day of sowing to achieve 60% germination was noted and expressed as DG_{60} (Swain *et al.*,2001).

3.1.3 Germination Per cent

From the samples sown for seed evaluation, the seedlings were evaluated on the tenth day of the emergence of the first seedling (final count day) and the total number of normal seedlings was recorded. The mean number of normal seedlings produced to the total number of seeds sown was expressed as germination percentage.

3.1.4 Speed of Germination

From the samples sown for seed evaluation, number of seedlings emerged was recorded daily until the tenth day of the emergence of first seedling. Cotyledons slipping out of the seed coat was taken as the criteria for emergence of normal seedling. From the mean germination percentage recorded on each counting date, speed of germination was calculated employing the following formula suggested by Maguire (1962).

$$\text{Speed of germination} = \frac{X_1}{Y_1} + \frac{X_2 - X_1}{Y_2} + \ldots\ldots\ldots\ldots + \frac{Xn - Xn_{-1}}{Yn}$$

Where Xn = Per cent germination on n^{th} day

Yn = number of days from sowing to n^{th} count.

3.1.5 Root Length of Seedling

At the end of the germination test period i.e. on the 10^{th} day, five normal seedlings were carefully uprooted at random from the test sample, measured the root length and the mean was computed. The length between collar and tip of the root was measured as root length and expressed in centimeter.

3.1.6 Shoot Length of Seedling

From the sample, after measuring root length, the length between collar and tip of the leaf was measured in cm the mean value was recorded as shoot length.

3.1.7 Vigour Index-I of Seedling

Vigour index-I was computed adopting the formula suggested by (Abdul-Baki and Anderson, 1973) and expressed as whole number.

Vigour index-I = Per cent Germination × Mean length of root and shoot in cm.

3.1.8 Seedling Dry Weight

Five normal seedlings were air dried initially for six hours and then in hot air oven maintained at 85^0 C for 24 hour. Dried seedlings were cooled in a desiccator for 45 minutes and the dry weight of single seedling was expressed in gram.

3.1.9 Vigour Index –II

Vigour index- II was computed, adopting the formula suggested by (Bewley and Black, 1982).

Vigour index- II = Per cent Germination × Seedlings dry weight in g.

3.1.10 Statistical Analysis

Statistical analysis of the data on seed quality parameters was performed using MSTAT-C package.

Considering the most important seed quality parameters like germination per cent, speed of germination, vigour index-I and II, the best six treatments were selected by analyzing the overall performance of treatments over six months.

3.2 STORAGE POTENTIAL OF INVIGORATED SEEDS

Fully matured uniform fruits were selected from the seed crop of ash gourd (KAU Local) raised during June- October 2003 as a rainy season crop and the seeds extracted from them were used for storage studies. The extracted seeds were after ripened for 2 months and then invigorated with the selected six treatments from 3.1 along with control (untreated seeds) and dried to a moisture content of 8 per cent. They were stored in 700 guage polythene covers under ordinary room temperature. The treatments were,

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.

T_7 - Control (untreated seeds)

Replication - 3
Design - CRD
Number of seeds / treatment - 50

The seed samples were drawn at monthly intervals and following quality parameters were recorded under laboratory conditions for six months.

3.2.1 Intensity of Dormancy -recorded as detailed under item 3.1.1

3.2.2 Days to achieve 60 per cent germination- recorded as detailed under item 3.1.2

3.2.3 Germination Percentage - recorded as detailed under item 3.1.3

3.2.4 Speed of Germination - recorded as detailed under item 3.1.4

3.2.5 Root length of Seedling - recorded as detailed under item 3.1.5

3.2.6 Shoot length of Seedling - recorded as detailed under item 3.1.6

3.2.7 Vigour Index - I of the Seedling - recorded as detailed under item 3.1.7.

3.2.8 Seedling Dry Weight - recorded as detailed under item 3.1.8

3.2.9 Vigour Index- II of the Seedling - recorded as detailed under item 3.1.9.

3.2.10 Electrical Conductivity of Seed Leachate- (Presley, 1958)

Two replications of twenty five seeds were taken and washed in distilled water to remove all adhering dirt, soil or chemicals. The seeds were then soaked in 20 ml of distilled water for four hours by occasionally stirring the contents. Then the seed leachate was decanted and seeds were washed with distilled water and all seed leachate were collected. Then seed leachate was filtered and made up to 50 ml. The electrical conductivity of seed leachate was measured in a digital conductivity meter (Type CM 180) with cell constant of electrode, one. The electrical conductivity of seed leachate was expressed as μ mhos/cm.

3.3. FIELD PERFORMANCE OF INVIGORATED SEEDS

Invigorated seeds (with those 6 selected methods from 3.1) were compared for field performance with seeds, whose dormancy has been broken naturally by storage.

The experiment was conducted during January- April2004. The crop was raised as summer season crop, adopting the recommended cultural operations and plant protection measures(KAU, 2003). The treatments include,

T_1 - Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.

T_2 - Extracted seeds from previous summer season crop, which is stored till sowing.

T_3 - Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.

T_4 - Extracted seeds from previous rainy season crop, which is stored till sowing

T_5 - Fresh seeds treated with GA_3 (25 ppm) for 24 hours.

T_6 - Fresh seeds treated with GA_3 (50 ppm) for 24 hours

T_7 - Fresh seeds treated with GA_3 (100 ppm) for 12 hours

T_8 - Fresh seeds treated with NAA (25 ppm) for 24 hours

T_9 - Fresh seeds treated with NAA (50 ppm) for 24 hours

T_{10} - Fresh seeds treated with 1 % KNO_3 for 12 hours

Number of treatments	-10
Design	- RBD
Replication	-3
Plot size	-36 m^2.

The following observations were recorded.

3.3.1 Field Emergence

A total number of 20 seeds were sown in each plot per treatment per replication. The number of germinated seedlings were counted on 10^{th} day after sowing and expressed as percentage.

3.3.2 Length of the Main Vine

The length of the main vine was recorded from collar region to tip of the vine in centimetre.

3.3.3 No of Primary Branches

The number of primary branches emerging from the main vine was counted.

3.3.4 Days to First Female Flower Opening

The number of days taken by the first female flower to open from the date of sowing was recorded.

3.3.5 Node at which First Female Flower Appeared

The node at which the first female flower appeared was counted from the cotyledonary node and recorded.

3.3.6 Per cent Fruit Set

The number of flower produced and fruits set were noted and the percentage calculated.

From each plot, half of the plants were retained for seed purpose and the remaining half was harvested at vegetable stage.

The following observations were recorded from plants retained for vegetable harvest.

3.3.7 Days to First Harvest for Vegetable Purpose

The number of days taken by the plants for first harvest for vegetable purpose from the date of sowing was recorded.

3.3.8 Single Fruit Weight

Weight of a single fruit before attaining ashy coating was taken from each plot, the average was worked out and expressed in grams.

3.3.9 Fruits per Plant

The number of fruits produced on the five observational plants were recorded and the mean was computed to get fruits per plant

3.3.10 Circumference of Fruit

The circumference of immature fruits before attaining ashy coating was measured at the middle of the fruit and expressed in centimetre.

3.3.11 Length of Fruit

Length of the fruit from the stalk end to the tip was recorded and expressed in centimetre.

3.3.12 Fruit Shape Index

Ratio of the fruit length to fruit diameter was recorded.

3.3.13 Fruit Yield per Plant

Total weight of the fruits harvested from each plant was recorded in kilograms.

3.3.14 Fruit Yield per Hectare

Fruit yield per hectare was calculated from net plant yield and expressed in kilograms. The following observations were recorded from plants retained for seed purpose.

3.3.15 Days to First Harvest for Seed Purpose

The number of days taken by the plants to attain ashy coating and drying of the peduncle was noted and days to first harvest for seed purpose from the date of sowing was recorded.

3.3.16 Single Fruit Weight at Seed Harvest

Recorded as detailed under item 3.3.8

3.3.17 Fruits per Plant at Seed Harvest

Recorded as detailed under item 3.3.9

3.3.18 Circumference of Fruit at Seed Harvest

Recorded as detailed under item 3.3.10

3.3.19 Length of Fruit at Seed Harvest

Recorded as detailed under item 3.3.11

3.3.20 Fruit Shape Index

Recorded as detailed under item 3.3.12

3.3.21 Fruit Yield per Plant

Recorded as detailed under item 3.3.13

3.3.22 Fruit Yield per Hectare

Recorded as detailed under item 3.3.14.

3.3.23 Seeds per Fruit

The number of seeds extracted from each mature fruit was counted and average recorded.

3.3.24 Hundred Seed Weight

Seeds extracted from the mature fruits of uniform size were washed, dried uniformly, hundred bold seeds were selected and the weight recorded in gram.

3.3.25 Seed Yield per Plot

Total weight of seeds collected from individual plot was recorded in grams

3.4 EVALUATION OF SEEDS EXTRACTED FROM THE FIELD STUDY.

Seeds extracted from the fruits collected from the field study (3.3) were evaluated for quality parameters under laboratory conditions and the following observations were recorded.

3.4.1 Germination Percentage - recorded as detailed under item 3.1.3

3.4.2 Speed of Germination - recorded as detailed under item 3.1.4

3.4.3 Vigour Index- I of the Seedling- recorded as detailed under item 3.1.7

Results

4. RESULT

The present investigation was carried out to standardise seed invigoration treatments to break dormancy in ash gourd, to study the storage potential and field performance of invigorated seeds. The experimental data collected were tabulated, analysed statistically and the results are presented in this chapter.

4.1 SEED INVIGORATION TO BREAK DORMANCY

4.1.1.a Intensity of Dormancy at Five Days after Sowing (NGS_5)

The intensity of dormancy at five days after sowing i.e. percentage of non germinated seeds at five days after sowing (NGS_5) was highly significant (Table 1.a) except at third month after extraction.

At 0 MAE seeds treated with NAA 100 ppm had maximum intensity of dormancy (NGS_5, 98.00) at five days of sowing, while minimum NGS_5(72.00) was shown by seeds treated with HNO_3 .At 1 MAE seeds treated with HCl exhibited highest NGS_5 (94.28) which was on par with all other treatments except seeds treated with GA_3 50 ppm and NAA 50 ppm. At 2 MAE seeds treated with hot water had highest NGS_5(85.71) and minimum value was exhibited by seeds treated with NAA 50 ppm (50.47). At 4 MAE untreated seeds recorded the highest NGS_5(88.33) value and the lowest value was recorded by seeds treated with GA_3 100 ppm (46.33) which was on par with seeds treated with H_2SO_4 (48.00). At 5 MAE seeds treated with HNO_3 had the maximum value (95.66), which was on par with seeds treated with NAA 100 ppm (91.66) and hot water (86.66).

Table 1.a. Effect of invigoration treatments on intensity of dormancy (NGS_5) at monthly intervals

	Intensity of dormancy (%)					
Treatments	**0 MAE**	**1 MAE**	**2 MAE**	**3 MAE**	**4 MAE**	**5 MAE**
T_1	85.33^{bc}	83.81^{a}	80.00^{abc}	90.47^{a}	48.00^{e}	69.00^{b}
T_2	82.66^{bcd}	94.28^{a}	77.45^{abc}	87.62^{a}	73.33^{abc}	62.33^{b}
T_3	72.00^{e}	78.09^{a}	58.09^{d}	90.48^{a}	86.67^{ab}	95.66^{a}
T_4	90.66^{ab}	85.71^{a}	65.72^{bcd}	89.52^{a}	76.67^{abc}	64.33^{b}
T_5	87.33^{b}	92.38^{a}	85.71^{a}	96.20^{a}	71.00^{bc}	86.66^{a}
T_6	89.33^{ab}	83.80^{a}	80.95^{ab}	88.57^{a}	51.33^{de}	28.33^{c}
T_7	84.00^{bc}	74.28^{ab}	66.66^{bcd}	83.81^{a}	66.00^{cd}	65.00^{b}
T_8	88.67^{b}	82.86^{a}	56.19^{d}	82.86^{a}	46.33^{e}	62.00^{b}
T_9	74.67^{de}	77.14^{a}	63.81^{cd}	81.90^{a}	53.33^{de}	61.33^{b}
T_{10}	88.00^{b}	58.09^{b}	50.47^{d}	75.24^{a}	73.00^{abc}	73.33^{b}
T_{11}	98.00^{a}	91.43^{a}	76.19^{abc}	83.81^{a}	76.00^{abc}	91.66^{a}
T_{12}	89.33^{ab}	88.57^{a}	54.29^{d}	89.52^{a}	60.00^{cde}	65.00^{b}
T_{13}	76.66^{cde}	90.47^{a}	78.10^{abc}	89.52^{a}	88.33^{a}	67.33^{b}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE: Month after extraction
Values having common superscript are not significantly different from one another.
NGS_5:Percentage non germinated seeds at five days after sowing

4.1.1.b Intensity of Dormancy at Ten Days after Sowing (NGS_{10})

The intensity of dormancy at ten days after sowing i.e percentage of non germinated seeds after ten days of sowing (NGS_{10}) at monthly intervals is given in Table 1.b

NGS_{10} was significant at all the months. Immediately after extraction (0MAE) seeds treated with hot water had maximum intensity of dormancy (80.00) while seeds treated with HNO_3 (55.33) had minimum NGS_{10}. At 1 MAE seeds treated with HCl had the highest value (91.43) and seeds treated with NAA 50 ppm has lowest intensity of dormancy (29.52). At 2 MAE and 3 MAE seeds treated with hot water had the highest NGS_{10} (76.19 and 75.24 respectively). Seeds treated with NAA 50 ppm exhibited lowest intensity (32.38) at 2 MAE and those treated with GA_3 50 ppm at 3 MAE (35.24).At 4 and 5 MAE seeds treated with HNO_3 had the highest NGS_{10} (61.67 and 59.30 respectively). The minimum NGS_{10} at 4 MAE was recorded by seeds treated with GA_3 100 ppm and NAA 25 ppm (31.00). At 5 MAE seeds treated with GA_3 25 ppm had the lowest value (6.67).

4.1.2 Days to Achieve 60 Per cent Germination (DG_{60})

The number of days to achieve sixty per cent germination (DG_{60}) is shown in Table 2

At 0MAE none of the treatments gave 60% germination. At 1 MAE seeds treated with NAA 50 ppm required minimum number of days to achieve sixty per cent germination (2.00 days). At 2MAE cold-water soaked seeds recorded minimum days to achieve 60 per cent germination (2.67) while the maximum days of 5.67 days was recorded by seeds treated with HNO_3, GA_3 25ppm and NAA 100ppm. At 3 MAE seeds treated with NAA 25ppm showed minimum (3 days) DG_{60} and GA_3 50 ppm treated seeds recorded the maximum days of 7.33.

Table 1.b. Effect of invigoration treatments on intensity of dormancy (NGS_{10}) at monthly intervals

	Intensity of dormancy(%)					
Treatments	**0 MAE**	**1 MAE**	**2 MAE**	**3 MAE**	**4 MAE**	**5 MAE**
T_1	77.33^{ab}	70.48^{ab}	70.477^{a}	71.430^{ab}	37.00^{cd}	35.33^{bcd}
T_2	74.67^{abc}	91.43^{a}	72.38^{a}	68.57^{ab}	53.33^{ab}	49.33^{ab}
T_3	55.33^{d}	73.33^{ab}	44.76^{bc}	63.81^{abc}	61.67^{a}	59.3^{a}
T_4	65.33^{bcd}	62.86^{bc}	41.90^{bc}	62.86^{abc}	56.67^{ab}	36.33^{bcd}
T_5	80.00^{a}	65.71^{bc}	76.19^{a}	75.24^{a}	51.33^{ab}	48.33^{abc}
T_6	70.67^{abc}	65.78^{bc}	36.19^{bc}	57.15^{bcd}	38.00^{cd}	6.67^{e}
T_7	65.33^{bcd}	59.05^{bc}	48.57^{b}	35.24^{e}	35.33^{cd}	26.00^{d}
T_8	71.33^{abc}	65.71^{bc}	40.95^{bc}	55.24^{bcd}	31.00^{d}	33.33^{cd}
T_9	60.67^{cd}	55.24^{bc}	44.76^{bc}	40.95^{de}	31.00^{d}	44.67_{bc}
T_{10}	72.00^{abc}	29.52^{d}	32.38^{c}	49.52^{cde}	59.67^{a}	47.00^{abc}
T_{11}	76.67^{ab}	71.43^{ab}	42.86^{bc}	60.00^{abc}	45.00^{bc}	43.33^{bc}
T_{12}	70.67^{abc}	72.38^{ab}	39.05^{bc}	55.24^{bcd}	36.67^{cd}	35.00^{bcd}
T_{13}	72.00^{abc}	47.62^{cd}	73.33^{a}	62.86^{abc}	48.33^{abc}	43.67^{bc}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE: Month after extraction
NGS_{10}: Percent non germinated seeds at 10 days after sowing
Values having common superscript are not significantly different from one another.

Table 2. Effect of invigoration treatments on number of days to achieve 60 per cent germination (DG_{60})

Treatments	Duration of dormancy(days)					
	0 MAE	1 MAE	2 MAE	3 MAE	4 MAE	5 MAE
T_1	-	-	-	-	7	5.33
T_2	-	-	-	-	2	-
T_3	-	-	5.67	-	-	-
T_4	-	-	2.67	-	-	3
T_5	-	-	-	-	-	3
T_6	-	-	5.67	-	4.33	3.33
T_7	-	-	-	7.33	7	6.67
T_8	-	-	4.67	3.33	6	3
T_9	-	-	3	3	4.33	2.33
T_{10}	-	2	4.33	-	-	-
T_{11}	-	6.33	5.67	-	2.67	3
T_{12}	-	-	4.33	-	7.67	5
T_{13}	-	-	-	-	-	-

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
- :indicate the treatments which did not give 60 per cent germination
MAE: Month after extraction

At 4 MAE seeds treated with HCl recorded minimum DG_{60} (2.00 days) where as maximum days was taken by seeds treated with KNO_3 1% (7.67). At 5 MAE seeds treated with NAA 25ppm required minimum days to achieve sixty per cent germination (2.33) whereas maximum DG_{60} was shown by seeds treated with GA_3 50 ppm (6.67). Untreated seeds never gave 60 per cent or more germination.

4.1.3 Germination Percentage

The germination percentage of seeds invigorated with different treatments at monthly intervals, was highly significant (Table 3).

Immediately after extraction (0MAE), seeds treated with HNO_3 showed the maximum germination percentage (44.67) and seeds soaked in hot water showed the minimum (20). At 1 MAE the maximum germination percentage was shown by seeds treated with 50ppm NAA (70.48) and HCl treated seeds recorded the minimum (7.62) germination percentage. At 2 MAE the maximum germination was again recorded in seeds treated with 50ppm NAA (67.62) and minimum was shown by untreated seeds (26.67). At 3 MAE maximum germination percentage was exhibited by seeds treated with GA_3 50ppm (64.76) and minimum germination per cent by H_2SO_4 treated seeds (28.57). At 4 MAE, seed treated with $GA_3$50 and 100 ppm recorded the highest (64.67 and 69.00 respectively) germination per cent. GA_3 25ppm treatment could result in seeds with maximum germination percentage (93.33) at 5MAE. HCl and HNO_3 treated seeds recorded the lowest germination during 4MAE (36.67 and 38.33 respectively) and HNO_3 treated seeds during 5MAE (40.67).

4.1.4 Speed of Germination

Results of the statistical analysis of the data on speed of germination are shown in Table 4.

Table 3. Effect of invigoration treatments on germination percent of ash gourd at monthly intervals

	Germination percent (%)					
Treatments	**0 MAE**	**1 MAE**	**2 MAE**	**3 MAE**	**4 MAE**	**5 MAE**
T_1	22.67 (0.49) ^{cd}	29.52 (0.57)^{c}	29.52 (0.57)^{c}	28.57 (0.56) ^{ef}	63.00 (0.92) ^{ab}	64.67 (0.94) ^{bc}
T_2	25.33 (0.52) ^{bcd}	7.62 (0.28)^{d}	27.62 (0.55)^{c}	31.43 (0.59)^{def}	36.67 (0.65)^{f}	50.67 (0.79) ^{cd}
T_3	44.67 (0.73)^{a}	26.67 (0.54)^{cd}	55.24 (0.84)^{ab}	36.19 (0.65)^{cdef}	38.33 (0.67)^{f}	40.67 (0.69)^{d}
T_4	34.67 (0.63)^{abc}	37.14 (0.65)^{bc}	58.10 (0.87)^{ab}	45.71 (0.74)^{bcd}	43.33 (0.72)^{def}	63.67 (0.93)^{bc}
T_5	20.00 (0.46)^{d}	34.29 (0.62)^{bc}	23.81 (0.50)^{c}	24.76 (0.52)^{f}	48.67 (0.77)^{cde}	51.67 (0.80)^{cd}
T_6	29.33 (0.57)^{bcd}	34.28 (0.62)^{bc}	63.81 (0.93)^{ab}	42.85 (0.71)^{bcde}	62.00 (0.91)^{ab}	93.33 (1.31)^{a}
T_7	34.67 (0.63)^{abc}	40.95 (0.69)^{bc}	51.43 (0.80)^{b}	64.76 (0.94)^{a}	64.67 (0.94)^{a}	74.00 (1.04)^{b}
T_8	28.67 (0.56)^{bcd}	34.29 (0.63)^{bc}	59.05 (0.88)^{ab}	44.76 (0.73)^{bcde}	69.00 (0.98)^{a}	65.00 (0.94)^{bc}
T_9	39.33 (0.68)^{ab}	44.76 (0.73)^{bc}	55.24 (0.84)^{ab}	59.05 (0.88)^{ab}	62.33 (0.91)^{ab}	60.00 (0.89)^{bc}
T_{10}	28.00 (0.56)^{bcd}	70.48 (1.00)^{a}	67.62 (0.97)^{a}	50.48 (0.79)^{abc}	40.33 (0.69)^{ef}	53.00 (0.82)^{cd}
T_{11}	23.33 (0.50)^{cd}	28.57 (0.56)^{cd}	57.14 (0.86)^{ab}	43.81 (0.72)^{bcde}	55.00 (0.84)^{bc}	56.67 (0.85)^{c}
T_{12}	29.33 (0.57)^{bcd}	27.62 (0.55)^{cd}	60.00 (0.89)^{ab}	44.76 (0.73)^{bcde}	61.33 (0.90)^{ab}	65.00 (0.94)^{bc}
T_{13}	28.00 (0.56)^{bcd}	52.38 (0.81)^{ab}	26.67 (0.54)^{c}	39.05 (0.67)^{cdef}	51.67 (0.80)^{cd}	56.33 (0.85)^{c}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE : Months after extraction.
Values having common superscript are not significantly different from one another.
Figures in parenthesis are arc- sine transformed values.

The effect of seed treatment on speed of germination was significant. At 0 month after extraction, HNO_3 treated seeds showed the maximum (8.66) speed of germination where as seeds treated with NAA100 ppm showed the minimum (3.41). At 1MAE, seed treatment with GA_3 100 ppm could result in the highest (14.29) speed of germination, where as HCl treated seeds showed the minimum (1.41). At 2 MAE the maximum speed of germination was recorded in seeds treated with 50ppm NAA (13.23). Minimum speed of germination was shown by H_2SO_4 and HCl treated seeds, seeds soaked in hot water, and the untreated seeds. GA_3 50ppm and NAA 25 ppm recorded the highest (10.58 and 9.54 respectively) speed of germination at 3 MAE, whereas the minimum speed of germination (3.93) was shown by seeds soaked in hot water. GA_3 100 ppm was effective in producing the highest (14.35) speed of germination at 4 MAE and GA_3 25 ppm(18.45) at 5MAE. HNO_3 treated seeds recorded the lowest speed of germination during 4 and 5MAE (6.56 and 5.57 respectively).

4.1.5 Root Length of Seedling

The effect of seed invigoration treatment on the root length of seedlings was significant at 0 MAE, 1 MAE, 4 MAE and 5 MAE as shown in Table 5

At 0 MAE, NAA 100 ppm recorded the maximum root length of 9.66 cm and GA_3 25 ppm (T_6) had the minimum length of 4.75cm. At 1 MAE the highest root length was recorded by NAA 25 ppm treated seeds (7.91), which was on par with T_4, T_7, T_{11} and T_{12}. The lowest root length (4.93) was recorded by hot water treated seeds. At 4 and 5 MAE untreated seeds produced seedlings with maximum root length of 7.89and 8.32 cm respectively. At 4 MAE, the minimum root length (5.45) was recorded in hot water treated seeds and GA_3 100 ppm treated seeds at 5 MAE (5.35).

Table 4. Effect of invigoration treatments on speed of germination of ash gourd at monthly intervals

	Speed of germination					
Treatments	**0 MAE**	**1 MAE**	**2 MAE**	**3 MAE**	**4 MAE**	**5 MAE**
T_1	4.23 ^{cd}	3.61 ^{cd}	5.59 ^{c}	4.87 ^{ef}	12.59 ^{abc}	11.27 ^{bcd}
T_2	4.58 ^{cd}	1.41 ^{d}	5.80 ^{c}	5.57 ^{def}	7.38 ^{fg}	10.05 ^{bcd}
T_3	8.66 ^{a}	4.81 ^{cd}	11.37 ^{ab}	5.97 ^{def}	6.56 ^{g}	5.57 ^{f}
T_4	5.70 ^{bcd}	4.87 ^{cd}	10.99 ^{ab}	7.87 ^{bcd}	8.16 ^{fg}	11.78 ^{bc}
T_5	3.70 ^{cd}	4.11 ^{cd}	4.76 ^{c}	3.93 ^{f}	9.34 ^{def}	8.07 ^{def}
T_6	4.97 ^{bcd}	5.45 ^{cd}	10.41 ^{ab}	6.91 ^{bcde}	13.13 ^{ab}	18.45 ^{a}
T_7	6.08 ^{bc}	6.93 ^{bc}	10.18 ^{ab}	10.58 ^{ab}	12.36 ^{abc}	13.38 ^{b}
T_8	4.79 ^{bcd}	14.29 ^{a}	11.92 ^{ab}	7.49 ^{abcde}	14.35 ^{a}	10.84 ^{bcd}
T_9	7.35 ^{ab}	7.23 ^{bc}	10.72 ^{ab}	9.54 ^{ab}	12.01 ^{bc}	9.97 ^{bcd}
T_{10}	4.87 ^{bcd}	11.45 ^{b}	13.23 ^{a}	8.89 ^{abc}	8.29 ^{efg}	6.30 ^{ef}
T_{11}	3.41 ^{d}	3.53 ^{cd}	9.77 ^{b}	7.17 ^{bcde}	9.14 ^{def}	9.14 ^{cde}
T_{12}	4.96 ^{bcd}	4.10 ^{cd}	12.34 ^{ab}	7.23 ^{bcde}	11.30 ^{bcd}	12.21 ^{bc}
T_{13}	5.78 ^{bcd}	7.89 ^{bc}	5.87 ^{c}	6.53 ^{cdef}	10.52 ^{cde}	10.94 ^{bcd}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4: Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE: Months after extraction.
Values having common superscript are not significantly different from one another.

Table 5. Effect of invigoration treatments on root length of ash gourd (cm) at monthly intervals

Treatments	Root length (cm)					
	0 MAE	1 MAE	2 MAE	3 MAE	4 MAE	5 MAE
T_1	5.48 ^{fg}	6.41 ^{abc}	6.12^{a}	5.25^{a}	6.49^{abcd}	8.13^{abc}
T_2	8.22 ^{bc}	5.22 ^{bc}	7.10^{a}	5.42^{a}	7.11^{abc}	6.47^{abcd}
T_3	5.22 ^{fg}	6.72 ^{abc}	6.73^{a}	5.90^{a}	7.31^{ab}	8.19^{ab}
T_4	7.34 ^{cd}	7.51 ^{a}	7.93^{a}	5.70^{a}	5.83^{cd}	6.09^{bcd}
T_5	7.48 ^{cd}	4.93^{c}	6.08^{a}	4.85^{a}	5.45^{d}	6.02^{cd}
T_6	4.75 ^{g}	6.72^{abc}	6.96^{a}	5.72^{a}	5.70^{cd}	6.70^{abcd}
T_7	5.55 ^{fg}	7.82^{a}	5.72^{a}	5.50^{a}	6.33^{bcd}	6.69 ^{abcd}
T_8	6.09 ^{ef}	7.01 ^{ab}	7.20^{a}	6.71^{a}	6.99^{abc}	5.35^{d}
T_9	9.20 ^{ab}	7.91^{a}	6.31^{a}	6.41^{a}	6.55^{abcd}	7.49^{abcd}
T_{10}	6.66^{de}	6.48^{abc}	6.13^{a}	5.89^{a}	6.83^{abcd}	7.54^{abc}
T_{11}	9.66 ^{a}	7.78^{a}	6.76^{a}	6.76^{a}	6.67^{abcd}	6.31^{abcd}
T_{12}	5.04 ^{fg}	7.44 ^{a}	6.63^{a}	6.73^{a}	6.67^{abcd}	6.23^{abcd}
T_{13}	6.02 ^{ef}	6.34 ^{abc}	6.18^{a}	6.25^{a}	7.89^{a}	8.32 ^{a}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE : Months after extraction.
Values having common superscript are not significantly different from one another.

4.1.6 Shoot Length of Seedling

Result of the statistical analysis of the data on shoot length of seedling is given in Table 6.

The effect of treatments on shoot length was significant only at 0 MAE, 1 MAE and at 4 MAE. At 0 MAE, hot water treatment and treatment with HNO_3 resulted in seedlings with maximum shoot length (11.98 and 11.94 cm respectively). NAA 50 ppm treated seeds recorded the minimum value of 9.81cm. At 1 MAE, NAA50 ppm treatment resulted in seedlings with maximum shoot length (12.09cm), which was on par with seeds treated with GA_3 100 ppm (11.91cm). Treatment with NAA 25 ppm resulted in seedlings with minimum shoot length of 8.90cm. Untreated seeds produced seedlings with a maximum value of 12.03 at 4 MAE and the minimum shoot length (9.45) was recorded by HNO_3 treated seeds.

4.1.7 Vigour Index-I of Seedling

Results of the statistical analysis of the data on vigour index-I of seedling are furnished in Table 7.

Seeds invigorated with NAA 25 ppm and HNO_3 recorded the maximum vigour index-I of 777 and 763 respectively at 0 MAE. H_2SO_4 treatment and hot water soaking could result in seeds with minimum (374 and 385 respectively) vigour index I at 0MAE. NAA 50 ppm induced maximum (1312) vigour index-I at 1MAE and HCl recorded the lowest (116) vigour during 1MAE. At 2 MAE seed invigoration using GA_3 25 and NAA 50 ppm resulted in production of seedlings with the highest vigour indices (1192 and 1207 respectively), whereas H_2SO_4, and HCl treated seeds, seeds soaked in hot water etc, were poor in performance along with the untreated seeds. At 3 MAE, GA_3 50 ppm treatment resulted in seeds having the maximum vigour index-I (1112). But the seeds

Table 6. Effect of invigoration treatments on shoot length (cm) of ash gourd at monthly intervals

	Shoot length (cm)					
Treatments	**0 MAE**	**1 MAE**	**2 MAE**	**3 MAE**	**4 MAE**	**5 MAE**
T_1	10.91^{abcd}	9.45^{bcd}	11.48^{a}	11.61^{a}	10.96^{abcd}	12.00^{a}
T_2	11.65^{ab}	10.11^{bcd}	12.12^{a}	10.96^{a}	11.58^{abc}	10.42^{a}
T_3	11.94^{a}	11.15^{ab}	11.70^{a}	13.34^{a}	9.45^{e}	13.75^{a}
T_4	11.59^{ab}	11.22^{ab}	9.72^{a}	11.50^{a}	10.00^{de}	11.65^{a}
T_5	11.98^{a}	9.38^{bcd}	11.17^{a}	11.12^{a}	10.07^{de}	9.26^{a}
T_6	10.56^{bcd}	9.19^{cd}	11.71^{a}	10.38^{a}	10.53^{bcde}	9.12^{a}
T_7	10.37^{bcd}	9.68^{bcd}	11.28^{a}	11.66^{a}	11.92^{ab}	14.79^{a}
T_8	10.27^{cd}	11.91^{a}	11.84^{a}	11.23^{a}	11.93^{ab}	12.97^{a}
T_9	10.64^{bcd}	8.90^{d}	11.17^{a}	11.35^{a}	10.41^{cde}	11.93^{a}
T_{10}	9.81^{d}	12.09^{a}	11.64^{a}	11.98^{a}	11.13^{abcd}	13.23^{a}
T_{11}	10.48^{bcd}	10.89^{abc}	11.37^{a}	10.18^{a}	9.78^{de}	12.13^{a}
T_{12}	10.59^{bcd}	10.80^{abc}	12.10^{a}	11.77^{a}	11.07^{abcd}	11.67^{a}
T_{13}	11.42^{abc}	9.65^{bcd}	11.67^{a}	11.51^{a}	12.03^{a}	7.74^{a}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE: Months after extraction.
Values having common superscript are not significantly different from one another.

Table 7. Effect of invigoration treatments on vigour index I of ash gourd at monthly intervals

Treatments	Vigour index I					
	0 MAE	1 MAE	2 MAE	3 MAE	4 MAE	5 MAE
T_1	374 ^{c}	469^{bc}	522 ^{c}	484 ^{ef}	1100^{bc}	1309^{abc}
T_2	503 ^{bc}	116 ^{e}	531 ^{c}	516 ^{def}	686 ^{e}	855^{cd}
T_3	763 ^{a}	476^{bc}	1019^{ab}	696 ^{cde}	641 ^{e}	895^{cd}
T_4	655 ^{ab}	693 ^{b}	1021^{ab}	786 ^{bcd}	683 ^{e}	1127^{abcd}
T_5	385 ^{c}	497 ^{b}	416 ^{c}	402 ^{f}	769 ^{de}	789^{d}
T_6	448 ^{bc}	549 ^{b}	1192 ^{a}	671^{cdef}	1006^{bc}	1472 ^{ab}
T_7	553 ^{abc}	713 ^{b}	874 ^{b}	1112^{a}	1176^{ab}	1589 ^{a}
T_8	484 ^{bc}	646 ^{b}	1125^{ab}	789^{bcd}	1305 ^{a}	1184^{abcd}
T_9	777 ^{a}	768 ^{b}	962 ^{ab}	1050 ^{ab}	1054^{bc}	1173^{abcd}
T_{10}	462 ^{bc}	1312^{a}	1207 ^{a}	901 ^{abc}	725de	1097^{abcd}
T_{11}	470 ^{bc}	529 ^{b}	1037^{ab}	743^{cde}	906^{cd}	1044^{bcd}
T_{12}	462 ^{bc}	505 ^{b}	1131^{ab}	834^{abc}	593^{e}	1163^{abcd}
T_{13}	487 ^{bc}	838 ^{b}	478 ^{c}	695^{cde}	1032^{bc}	1051^{bcd}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE: Months after extraction.
Values having common superscript are not significantly different from one another.

soaked in hot water recorded the lowest (402) vigour index. At 4MAE, GA_3 100 ppm treated seeds recorded the maximum vigour index-I (1305) and GA_3 50 ppm (1589) at 5MAE. Hot water soaking produced seeds with minimum (789) vigour index at the end of the experiment.

4.1.8 Seedling Dry Weight

Table 8 shows the effect of seed invigoration on seedling dry weight at monthly intervals.

The effect of the treatment was significant only at 0 and 3 MAE. At 0 MAE invigoration with GA_3 100 ppm resulted in the highest seedling dry weight of 0.098g. Seed treatment with NAA 50 ppm recorded the lowest (0.011g) seedling dry weight. Cold and hot water soaking and treatment with NAA 25 ppm were on par. At 3MAE, KNO_3 treated seeds recorded maximum (0.092g) seedling dry weight, which was on par with seeds treated with NAA 25 ppm (0.087g) and GA_3 100ppm (0.085g). HCl treatment resulted in lowest seedling dry weight of 0.047g.This was on par with seeds treated with HNO_3, hot water and untreated seeds.

4.1.9 Vigour Index –II

Results of the statistical analysis of the data on vigour index-II of seedling revealed that the invigoration treatments were significant in influencing the vigour index- II of the seedling during all the months except at 5MAE (Table 9).

At 0 MAE, HNO_3 treated seed recorded the maximum (3.88) vigour index-II. GA_3 50 ppm registered maximum vigour index -II at 1 and 2 MAE (4.34 and 5.12 respectively). HCl treated seeds recorded the lowest vigour index-II (0.38) at 1 MAE and the untreated seeds at 2 MAE (1.75). NAA 25ppm treatment was effective in producing seeds with maximum vigour index-II, both at 3 and 4

Table 8. Effect of invigoration treatments on seedling dry weight (g) of ash gourd at monthly intervals

	Seedling dry weight(g)					
Treatments	**0 MAE**	**1 MAE**	**2 MAE**	**3 MAE**	**4 MAE**	**5 MAE**
T_1	0.083 ^{ab}	0.048^{a}	0.059^{a}	0.063^{bc}	0.011^{a}	0.058^{a}
T_2	0.024 ^{dc}	0.037^{a}	0.010^{a}	0.047^{c}	0.092^{a}	0.010^{a}
T_3	0.088^{ab}	0.074^{a}	0.078^{a}	0.053^{c}	0.078^{a}	0.075^{a}
T_4	0.014^{c}	0.083^{a}	0.075^{a}	0.063^{bc}	0.099^{a}	0.063^{a}
T_5	0.013^{c}	0.048^{a}	0.093^{a}	0.054 ^{c}	0.087^{a}	0.092^{a}
T_6	0.083^{ab}	0.052^{a}	0.074^{a}	0.064^{bc}	0.092^{a}	0.074^{a}
T_7	0.086 ^{ab}	0.054^{a}	0.059^{a}	0.063^{bc}	0.010^{a}	0.059^{a}
T_8	0.098 ^{a}	0.069^{a}	0.062^{a}	0.085^{a}	0.098^{a}	0.062^{a}
T_9	0.016 ^{e}	0.046^{a}	0.087^{a}	0.087^{a}	0.011^{a}	0.086^{a}
T_{10}	0.011^{e}	0.061^{a}	0.074^{a}	0.063^{bc}	0.097^{a}	0.074^{a}
T_{11}	0.038^{d}	0.051^{a}	0.067^{a}	0.078^{ab}	0.010^{a}	0.066^{a}
T_{12}	0.071^{bc}	0.083^{a}	0.051^{a}	0.092^{a}	0.092^{a}	0.052^{a}
T_{13}	0.062^{c}	0.056^{a}	0.065^{a}	0.052^{c}	0.099^{a}	0.065^{a}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE : Months after extraction.
Values having common superscript are not significantly different from one another.

Table 9. Effect of invigoration treatments on vigour index II of ash gourd at monthly intervals

	Vigour index II					
Treatments	**0 MAE**	**1 MAE**	**2 MAE**	**3 MAE**	**4 MAE**	**5 MAE**
T_1	1.88^{cde}	1.43^{de}	1.89^{cd}	1.80^{cde}	7.02^{a}	3.86^{a}
T_2	0.62^{f}	0.38^{e}	2.79^{abcd}	1.55^{de}	3.36^{e}	5.25^{a}
T_3	3.88^{a}	1.91^{bcd}	4.12^{abc}	1.91^{cde}	2.99^{e}	3.19^{a}
T_4	0.52^{f}	3.05^{d}	4.37^{ab}	2.89^{bcde}	4.32^{cde}	4.17^{a}
T_5	0.26^{f}	1.70^{cd}	2.52^{bcd}	1.33^{e}	4.30^{cde}	4.82^{a}
T_6	2.45^{bcd}	1.75^{bcd}	4.72^{ab}	2.72^{bcde}	5.69^{abc}	6.92^{a}
T_7	2.99^{ab}	2.27^{bcd}	3.00^{abcd}	4.08^{ab}	6.74^{ab}	4.29^{a}
T_8	0.89^{abc}	2.31^{bcd}	3.66^{abcd}	3.69^{abc}	6.76^{ab}	4.03^{a}
T_9	0.57^{f}	2.02^{bcd}	4.79^{ab}	5.20^{a}	7.16^{a}	5.22^{a}
T_{10}	0.31^{f}	4.34^{a}	5.12^{a}	3.20^{bcde}	3.93^{de}	3.88^{a}
T_{11}	0.89^{ef}	1.41^{de}	3.82^{abcd}	3.46^{abcd}	5.45^{bc}	3.74^{a}
T_{12}	2.08^{bcd}	2.27^{bcd}	3.08^{abcd}	4.10^{ab}	3.07^{e}	3.31^{a}
T_{13}	1.73^{de}	2.94^{bc}	1.75^{d}	2.00^{cde}	5.17^{cd}	3.85^{a}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)
MAE : Months after extraction.
Values having common superscript are not significantly different from one another.

MAE (5.20 and 7.16 respectively). H_2SO_4 was also effective in producing seeds with maximum vigour index-II(7.02) at 4MAE.

4.1.10 Overall Performance of Different Treatments Over a Period of Six Months.

Overall performance of various invigoration treatments over a period of six months showed significant variation for different characters (Table 10)

The most important seed quality parameters like germination percentage, speed of germination, vigour index- I and II were considered for the analysis. Considering the germination percentage GA_3 50 ppm showed best performance followed by, GA_3 at 25ppm, NAA at 25 and 50 ppm and GA_3 100 ppm. Seed treatment with HCl resulted in lowest germination (29.89) followed by hot water treatment, H_2SO_4 and HNO_3. GA_3 100 ppm gave the highest (13.94) speed of germination. GA_3 25 and 50ppm were the second best in improving speed of germination. HCl and hot water treatment gave lowest speed of germination (5.80 and 5.65 respectively). GA_3 50 ppm recorded maximum (1003) vigour index I, which was on par with NAA 25 and 50 ppm. GA_3 100 ppm also gave superior (922) vigour index I.Seed treatment with HCl and hot water produced lowest vigour index I (534 and 543 respectively).NAA 25 ppm gave maximum (4.18) vigour index II, followed by GA 25 ppm (4.04), GA_3 50 and 100 ppm (3.89). Seed treatment with HCl recorded lowest (2.32) vigour index II followed by hot water treatment (2.49). Considering all these parameters together, GA_3 25,50, 100 ppm, NAA25 and 50 ppm were ranked as the best five treatments. As per the references collected, seed invigoration using KNO_3 has positive influence on seed quality aspects in many crops. So KNO_3 was also selected for further studies.

Table 10. Analysis of overall performance of invigoration treatments on seed quality parameters, over a period of six months

Treatments	Germination %	Speed of germination	Vigour index I	Vigour index II
T_1	39.66^{fg}	7.02^{ef}	709^{d}	2.98^{cde}
T_2	29.89^{h}	5.80^{f}	534^{e}	2.32^{e}
T_3	40.29^{f}	7.16^{def}	749^{d}	3.00^{cde}
T_4	47.10^{cde}	8.23^{cde}	828^{bcd}	3.22^{abcd}
T_5	33.86^{gh}	5.65^{f}	543^{e}	2.49^{de}
T_6	54.27^{ab}	9.89^{b}	890^{abc}	4.04^{ab}
T_7	55.08^{a}	9.92^{b}	1003^{a}	3.89^{abc}
T_8	50.13^{abcd}	13.94^{a}	922^{ab}	3.89^{abc}
T_9	53.45^{abc}	9.47^{bc}	964^{a}	4.18^{a}
T_{10}	51.65^{abc}	8.84^{bc}	950^{a}	3.46^{abcd}
T_{11}	44.09^{def}	7.02^{ef}	788^{cd}	3.13^{bcde}
T_{12}	48.01^{bcde}	8.69^{bcd}	781^{cd}	2.98^{cde}
T_{13}	42.35^{ef}	7.92^{cde}	764^{d}	2.91^{cde}

T_1: 5N H_2SO_4 for 10 minutes
T_2: 5N HCl for 30 minutes
T_3: 5N HNO_3 for 20 minutes
T_4:Water soaking for 8 hours
T_5: Hot water (40^0 C) soaking for 5 minutes
T_6: GA_3 (25 ppm) for 24 hours
T_7: GA_3 (50 ppm) for 24 hours
T_8: GA_3 (100 ppm) for 12 hours
T_9: NAA (25ppm) for 24 hours
T_{10}: NAA(50 ppm)for 24 hours
T_{11}: NAA(100ppm) for 12 hours
T_{12}: 1% KNO_3 for 12 hours
T_{13}: Control (untreated seeds)

Values having common superscript are not significantly different from one another.

4.2. STORAGE POTENTIAL OF INVIGORATED SEEDS

4.2.1.a Intensity of Dormancy at Five Days after Sowing (NGS_5)

The effect of storage on intensity of dormancy at 5 days after sowing of invigorated seeds is presented in Table 11.a.

The intensity of dormancy between treatments within each month did not show any significant variation. The mean intensity of dormancy recorded over the period of storage showed significant difference. The maximum intensity was recorded at 6MAS(68.76) which was on par with the intensity at 4 and 2 MAS .The NGS_5 value was minimum at 3 MAS (55.81)

Among various treatments, untreated seeds had the maximum intensity of dormancy at five days of sowing (70.22) which was on par with seeds treated with GA_3 25 ppm (66.67) and NAA 50 ppm (66.00) . Seeds treated with KNO_3 1 % recorded the minimum value (57.11).

4.2.1.b Intensity of Dormancy at Ten Days of Sowing (NGS_{10})

Table 11.b shows the effect of storage on the intensity of dormancy of invigorated seeds at 10 days of sowing.

The NGS_{10} value among different treatments within each month showed significant difference except at 2 MAS. At 1 MAS the maximum NGS_{10} value was recorded by untreated seeds (33.33). All other treatments were on par. However the minimum value was recorded by NAA 50 ppm (5.33). At 3 MAS, the seeds treated with GA 25 ppm had highest NGS_{10} value (45.33). which was on par with GA_3 50 ppm (37.33) and NAA 50 ppm (36.00). The lowest NGS_{10} (12.00) value was recorded by KNO_3 1%, which was on par with untreated seeds (13.33) and seeds treated with GA_3 100 ppm (16.00). At 4MAS untreated seeds (36.00) were on par with all other treatments except GA_3 100 ppm (22.67) which

Table 11.a. Effect of storage on intensity of dormancy (NGS_5) of invigorated seeds.

Intensity of dormancy (%)							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	61.33	64.00	64.00	70.67	66.67	73.33	66.67
T_2	65.33	65.33	60.00	52.00	64.00	64.00	61.78
T_3	58.67	57.33	58.67	76.00	56.00	61.33	61.33
T_4	56.00	54.67	57.33	80.00	56.00	66.67	61.78
T_5	68.00	72.00	56.00	65.33	70.67	64.00	66.00
T_6	54.67	62.67	37.33	58.67	58.67	70.67	57.11
T_7	69.33	80.00	57.33	74.67	58.67	81.33	70.22
Mean	61.905	65.14	55.81	68.19	61.52	68.76	

C.D for months=4.96
C.D. for treatments=6.60
C.D. for treatment within months=NS

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS : months after storage
NS:Non significant

Table 11.b. Effect of storage on the intensity of dormancy (NGS_{10}) of invigorated seeds.

Intensity of dormancy (%)							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	8.00	24.00	45.33	33.33	49.33	50.67	35.11
T_2	8.00	18.67	37.33	34.67	36.00	33.33	28.00
T_3	12.00	18.67	16.00	22.67	30.67	29.33	21.56
T_4	9.33	17.33	29.00	28.00	24.00	33.33	23.56
T_5	5.33	22.67	36.00	32.00	30.67	44.00	28.44
T_6	9.33	16.00	12.00	34.67	33.33	50.67	26.00
T_7	33.33	17.33	13.33	36.00	30.67	44.00	29.11
Mean	12.19	19.24	27.05	31.62	33.52	40.76	

C.D. for months:6.92
C.D. for treatments:4.71
C.D. for treatments within months :11.54

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS-Months after storage
NS -Non significant

had the minimum value. The seeds treated with GA_3 25 ppm had the highest NGS_{10} value during 5 MAS (49.33) and 6 MAS (50.67).

The NGS_{10} showed a gradual increase during the period of storage from 12.19 at 1MAS to 40.76 at 6 MAS. Maximum NGS_{10} was recorded at 6 MAS (40.76), which was followed by 5 MAS (33.52). NGS_{10} at 3, 4 and 5 MAS were on par with each other. Minimum NGS_{10} was recorded at 1 MAS (12.19)

Among the treatments, the highest value of NGS_{10} was recorded by GA_3 25 ppm treated seeds (35.11), which was followed by untreated seeds (29.11). The seeds treated with GA_3 100 ppm recorded the minimum NGS_{10} value (21.56) which was on par with NAA 25 ppm treated seeds (23.56) and seeds treated with KNO_3 1 % (26.00).

4.2.2 Days to Achieve 60 Per cent Germination

The number of days to achieve 60 per cent germination was significant (Table 12).

At 1 MAS the untreated seeds took maximum days (10.00), which was on par with GA_3 50 ppm (8.00). However GA_3 50 ppm (8.00) was on par with all other treatments. DG_{60} was non significant at 2 and 4 MAS. At 3 MAS GA_3 25 ppm did not achieve 60 per cent germination. GA_3 100 ppm had maximum value (7.67), which was on par with all other treatments. At 5 MAS, NAA 50 ppm required maximum days (9.00), which was on par with all other treatments except GA_3 25 ppm (5.00). At 6 MAS, NAA 25 ppm had the highest DG_{60}(8.67) while $GA_3$50 ppm had minimum DG_{60} (4.00).

The overall mean of number of days to achieve 60 per cent germination during six months of storage was significant. At 2 MAS maximum days to

Table 12. Effect of storage on number of days to achieve 60 per cent germination (DG_{60})

Days to achieve 60 percent germination							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	6.67	8.67	-	7.33	5.00	5.67	5.5
T_2	8.00	8.67	5.67	7.33	8.67	4.00	7.05
T_3	7.00	8.67	7.67	8.33	7.67	7.67	7.83
T_4	6.33	8.33	6.33	8.33	7.33	8.67	7.56
T_5	7.67	8.00	7.00	7.33	9.00	5.00	7.33
T_6	7.33	8.67	5.67	9.00	7.00	-	6.28
T_7	10.00	8.67	6.00	8.00	6.67	7.00	7.72
Mean	7.57	8.52	5.48	7.95	7.33	5.43	

C.D. for months:1.60
C.D. for treatments:1.09
C.D. for treatments within months:2.67

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS -Months after storage
NS -Non significant

Plate 2. Performance of invigorated seeds at 1 MAS

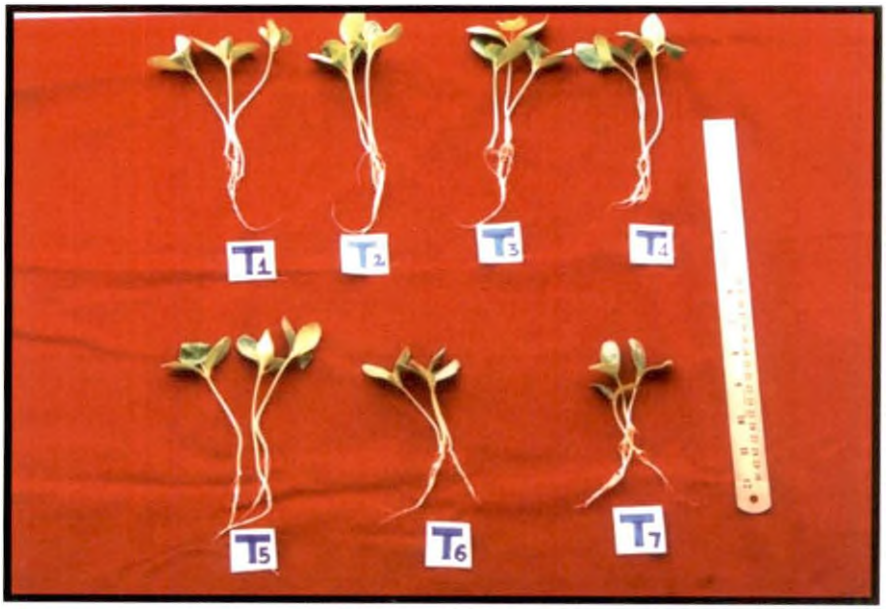

Plate 3. Seedling vigour after six months of storage

achieve 60 per cent germination (8.52) was recorded and minimum days was recorded at 6 MAS (5.43), which was on par with 3 MAS.

The overall mean of number of days to achieve 60 per cent germination between treatments was highly significant. Seeds treated with GA_3 100 ppm required maximum days (7.83) which was on par with all other treatments except seeds treated with KNO_3 (6.28) and GA_3 25 ppm (5.5)

4.2.3 Germination Percentage

Table 13 shows the effect of storage on germination per cent of invigorated seeds. The overall mean germination per cent of invigorated seeds within each month was highly significant except at 2 and 6 MAS.

At 1MAS, NAA 50 ppm treated seeds recorded the maximum (94.67%) germination per cent which was on par with all other treatments except untreated seeds, which showed a germination of 66.67 per cent . At 3MAS, seeds treated with KNO_3 1 % and GA_3 100 ppm showed the highest germination per cent (84.00) which was on par with untreated seeds (77.33). At 4 MAS, the maximum germination was recorded by GA_3 100 ppm (77.33) which was on par with NAA 25 ppm (72.00) , NAA 50 ppm (68.00) and seeds treated with GA_3 25 ppm (66.67) . At 5MAS,seeds treated with NAA 25 ppm had the maximum germination (76.00), which was on par with all other treatments except those treated with GA_3 25 ppm.(50.67).

There was a gradual reduction in the overall mean germination per cent of treated seeds during the period of storage from 87.81 to 59.26 per cent. The highest germination (87.81) was recorded at 1 MAS, which was on par with that at 2MAS(80.76). Germination per cent at 3MAS (71.05) was on par with that recorded at 4MAS (68,38) and 5 MAS (67.43). The lowest germination (59.26). per cent was recorded at 6 MAS.

Table 13. Effect of storage on germination percent of invigorated seeds

Germination percent							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	92.00 (9.61)	76.00 (8.74)	54.67 (7.43)	66.67 (8.19)	50.67 (7.15)	49.33 (6.90)	64.89 (8.00)
T_2	92.00 (9.62)	81.33 (9.04)	62.67 (7.95)	65.33 (8.11)	64.00 (8.03)	66.67 (8.18)	72.00 (8.49)
T_3	88.00 (9.41)	81.33 (9.85)	84.00 (9.18)	77.33 (8.81)	74.67 (8.67)	70.67 (8.43)	79.33 (8.92)
T_4	90.67 (9.55)	82.67 (9.09)	70.67 (8.43)	72.00 (8.51)	76.00 (8.74)	66.67 (8.19)	76.44 (8.75)
T_5	94.67 (9.76)	77.33 (8.82)	64.00 (8.02)	68.00 (8.27)	65.33 (8.10)	56.00 (7.48)	70.89 (8.41)
T_6	90.67 (9.54)	84.00 (9.20)	84.00 (9.18)	65.33 (8.11)	68.00 (8.27)	49.33 (7.05)	73.56 (8.56)
T_7	66.67 (8.19)	82.67 (9.12)	77.33 (8.82)	64.00 (8.03)	73.33 (8.59)	56.00 (7.52)	70.00 (8.33)
Mean	87.81 (9.38)	80.76 (9.00)	71.05 (8.43)	68.38 (8.29)	67.43 (8.22)	59.26 (7.68)	
C.D for months :0.39 C.D for treatments:0.28 C.D for treatment within months:0.69							

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
Figures in parenthesis are arc- sine transformed values
MAS : months after storage.

Table 14. Effect of storage on speed of germination of invigorated seeds

Speed of germination							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T1	15.92	13.30	11.05	12.94	10.69	9.75	12.28
T2	15.31	14.25	12.36	14.64	11.85	11.36	13.29
T3	15.51	14.75	15.91	14.81	14.20	12.16	14.45
T4	16.31	15.21	14.53	13.97	13.38	10.81	14.04
T5	15.50	13.13	13.65	13.69	12.09	10.97	13.17
T6	15.88	14.77	18.01	13.06	13.19	8.31	13.87
T7	12.15	12.82	16.04	11.99	13.44	10.16	12.77
Mean	15.23	14.03	14.51	13.50	12.69	10.50	

C.D for months: 1.10
C.D for treatments:0. 93
C.D. for treatment within months: 2.23

MAS : months after storage
T_1 - GA_3 (25 ppm) for 24 hours
T_2 - GA_3 (50 ppm) for 24 hours
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)

Seeds treated with GA_3 100 ppm recorded maximum germination (79.33) which was on par with seeds treated with NAA 25 ppm (76.44). Seeds treated with GA_3 25 ppm exhibited the minimum germination percent (64.89).

4.2.4 Speed of Germination

The effect of storage on speed of germination of invigorated seeds is shown in Table 14

The speed of germination of different treatments within each month was found to be significant. The seeds treated with NAA 25 ppm was found to have maximum speed of germination during 1MAS and 2MAS (16.31 and 15.21 respectively). Though having maximum value, these treatments were on par with all other treatments except untreated seeds (T_7), which showed a minimum value of 12.15 and 12.82 during 1 and 2 MAS. At 3MAS seeds treated with KNO_3 1% had the highest value (18.01), which was on par with, untreated seeds (16.04) and seeds treated with GA_3 100 ppm (15.91). The speed of germination of untreated seeds was the minimum (11.99) during 4 MAS. All other treatments showed superior performance. At 5 MAS and 6 MAS, $GA_3$100 ppm seed treated had maximum speed of germination (14.20 and 12.16 respectively).

The overall mean speed of germination during different months showed significant difference when averaged over treatments. Maximum speed of germination (15.23) was shown during 1MAS which was on par with that at 3MAS (14.51). The speed of germination recorded during 2MAS (14.03) was on par with that at 4 MAS (13.5). Speed of germination was least (10.5) during 6 MAS.

The overall mean speed of germination was significantly different for different treatments when averaged over months. The highest speed of germination was recorded with GA_3 100 ppm (14.45) which was on par with

seeds treated with NAA 25 ppm (14.04) and KNO_3 1 per cent (13.87). Seeds treated with GA_3 50 ppm (13.29), NAA 50 ppm (13.17) and untreated seeds (12.77) were on par. Minimum speed of germination was shown by GA_3 25 ppm treated seeds (12.28).

4.2.5 Root Length of Seedling

The effect of storage on the root length of seedling raised from invigorated seeds is presented in Table 15

The root length of seedling showed significant difference between treatments within each month. At 1MAS the maximum root length (6.75) was shown by seeds treated with GA_3 50 ppm which was on par with all other treatment except those treated with KNO_3 1 % (5.43). GA_3 100 ppm treated seeds had highest speed at 2 MAS (9.43) which was on par with GA_3 50 ppm (8.91). At 3 MAS, GA_3 50 ppm (9.28) and 100 ppm (8.52) resulted in maximum rootlength while GA_3 25 ppm treated seeds had the lowest rootlength (6.00). Untreated seeds and seeds treated with NAA 25 ppm (6.73) had the maximum root length at 4 MAS. The root length did not show any significant difference between treatments at 5 and 6MAS.

The overall mean root length of seedling pooled over months showed significant difference between treatments. The maximum root length was recorded for seeds treated with GA_3 50 ppm (7.09), which was on par with GA_3 100 ppm treated seeds (6.80). The latter was on par with NAA 25 ppm treated seeds (6.54). The minimum root length (5.98) was recorded by seeds treated with KNO_3 1 %.

The overall mean root length showed significant difference between different months. The maximum root length (7.34) was recorded at 3 MAS, which was on par with rootlength recorded at 2MAS. Root length recorded during rest of the months did not show any significant difference.

Table .15 Effect of storage on root length of invigorated seeds.

Root length(cm)							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	6.18	7.11	6.00	5.49	5.71	5.84	6.06
T_2	6.75	8.91	9.28	6.29	5.54	5.82	7.09
T_3	6.54	9.43	8.52	5.64	5.34	5.31	6.80
T_4	5.54	7.29	7.500	6.73	6.61	5.57	6.54
T_5	6.23	6.09	7.36	5.28	6.25	5.72	6.15
T_6	5 .43	6.19	6.59	6.37	5.98	5.39	5.98
T_7	5.99	6.29	6.13	6.73	5.54	6.05	6.12
Mean	6.10	7.33	7.34	6.08	5.85	5.67	

C.D. for months=0.54
C.D. for treatments=0.53
C.D. for treatment within months=1.30

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS - Months after storage
NS - Non significant

4.2.6 Shoot Length of Seedling

Table 16 shows the data on the effect of storage on shoot length of seedling produced from invigorated seeds.

The effect of storage on shoot length shows significant difference only between treatments with in each month. The overall mean shoot length was significant only at 3 MAS and 6 MAS. At 3MAS,seeds treated with KNO3 1% showed the maximum shoot length (16.54), which was followed by $GA_3$100 ppm treated seeds (11.13). Untreated seeds had the minimum value (9.13). At 6 MAS, seeds treated with NAA 50 ppm had the maximum (12.90) shoot length which was on par with all other treatments except untreated seeds, which recorded the minimum value of 7.71 cm.

4.2.7 Vigour Index - I of the Seedling

Table 17 shows the effect of storage on vigour index I of invigorated seeds.

Seeds treated with GA_3 50ppm recorded maximum (1720) vigour index I during 1 MAS which was on par with all other treatments except control (1138). At 2MAS seeds treated with GA_3 100 ppm recorded maximum vigour index I (1695), which was on par with GA_3 50 ppm (1637), GA_3 25 ppm (1407) and control (1399). At 3MAS, KNO_3 1 % (1889) was superior in performance and the least value (857) of vigour index I was recorded by GA 25 ppm. The NAA 25 ppm treated seeds showed the highest value of 1362 and 1273 at 4 and 5MAS respectively. At 6MAS, GA_3 100 ppm treated seeds having highest value (1246) was on par with seeds treated with NAA 25 ppm (1181) GA 50 ppm (1103) and NAA 50 ppm (1037). Un treated seeds recorded the minimum value (770) at 6 MAS. .

Table 16. Effect of storage on shoot length of invigorated seeds.

Shoot length (cm)							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	9.31	11.400	9.71	11.75	8.91	9.93	10.17
T_2	11.95	11.260	9.48	13.00	10.29	10.69	11.11
T_3	10.12	11.38	11.13	11.19	10.78	12.35	11.16
T_4	11.85	8.49	10.01	12.23	10.16	12.14	10.81
T_5	11.85	8.85	9.42	10.23	11.05	12.90	10.72
T_6	11.09	10.00	16.54	11.19	11.66	10.37	11.81
T_7	11.04	10.53	9.13	11.54	10.74	7.71	10.12
Mean	11.03	10.27	10.78	11.59	10.51	10.87	

C.D. for months =NS
C.D. for treatments=NS
C.D. for treatment within months=3.22

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS -Months after storage
NS -Non significant

Table 17. Effect of storage on vigour index I of invigorated seeds

Vigour index I							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	1416	1407	857	1149	753	793	1061
T_2	1720	1637	1173	1262	1011	1103	1318
T_3	1466	1695	1644	1301	1204	1246	1426
T_4	1581	1292	1233	1362	1273	1181	1320
T_5	1713	1155	1068	1058	1132	1037	1194
T_6	1497	1378	1889	1151	1193	778	1314
T_7	1138	1399	1185	1169	1194	770	1143
Mean	1505	1423	1293	1207	1107	987	

C.D. for months:96.41
C.D. for treatment:125.35
C.D. for treatment within months:307.09

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS : months after storage

The overall mean vigour index I recorded during different months showed a gradual reduction from 1505 at 1MAS to 987 during 6MAS. The vigour index I recorded at one month after storage was on par with the vigour recorded at two months of storage.

Considering the treatments, seeds invigorated with GA_3 100 ppm had maximum vigour index I (1426) which was on par with NAA 25 ppm (1320), GA 50 ppm (1318) and KNO_3 1 % (1314). Minimum vigour index I was recorded by GA 25 ppm (1061) which was on par with untreated seeds (1143).

4.2.8 Seedling Dry Weight

Table 18 shows the effect of storage on seedling dry weight of invigorated seeds.

The mean seedling dry weight pooled over months between treatments and treatments within each month remained non significant. The mean seedling dry weight recorded during different months showed significant differences. The maximum seedling dry weight was recorded at 2 MAS (0.103), which was on par with seedling dry weight at 4MAS(0.087), 1 MAS (0.083) and at 5MAS (0.080). Seedling dry weight recorded at 3 MAS was the least (0.066).

4.2.9 Vigour Index - II of the Seedling

The effect of storage on vigour index II of invigorated seeds is shown in Table 19.

The vigour index II for different treatments and treatments within each month did not show any significant variation.

Mean vigour index II was significantly different for different months. During storage the maximum value of vigour index II was recorded at 2MAS

Table 18. Effect of storage on the seedling dry weight of invigorated seeds

Seedling dry weight (g)							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	85.21	99.21	74.00	77.23	80.43	63.21	80.14
T_2	89.10	84.10	57.21	83.42	79.11	72.14	77.24
T_3	10.60	95.62	57.22	10.26	73.14	83.33	85.44
T_4	85.10	21.09	73.51	78.44	78.14	69.47	10.10
T_5	77.14	84.10	72.04	10.04	77.17	78.55	81.32
T_6	77.31	67.33	58.33	79.31	10.48	72.04	75.44
T_7	67.10	75.22	74.14	84.41	75.47	59.03	72.41
Mean	0.083	10.13	66.44	87.31	80.34	71.44	

C.D. for months= 0.025
C.D. for treatments=NS
C.D. for treatment within months=NS

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS -Months after storage
NS -Non significant

Table 19. Effect of storage on vigour index II of invigorated seeds .

Vigour index II							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	7.74	7.49	4.06	5.16	4.05	3.25	5.29
T_2	8.22	6.88	3.55	5.45	5.03	4.85	5.66
T_3	8.80	7.73	4.66	8.19	5.40	5.86	6.77
T_4	7.65	18.43	5.14	5.59	5.92	4.58	7.88
T_5	7.34	6.49	4.61	6.78	4.98	4.25	5.74
T_6	6.89	5.60	4.85	5.18	6.77	3.49	5.46
T_7	4.44	6.22	5.74	5.38	5.57	3.32	5.11
Mean	7.29	8.41	4.66	5.96	5.38	4.23	
C.D. for months=2.27 C.D. for treatments=NS C.D. for treatments within months=NS							

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
NS - Non significant
MAS : months after storage

(8.41) which was on par with the value at 1 MAS (7.29). The lowest vigour index II (4.23) was recorded at 6 MAS.

4.2.10 Electrical Conductivity of Seed Leachate.

The effect of storage on the electrical conductivity of invigorated seed is shown in Table 20.

Maximum electrical conductivity was recorded by KNO_3 1 % (72.08) and NAA 50 ppm (36.52) remained lowest throughout the period of storage. Electrical conductivity showed significant difference between different treatments, months and different treatments within each month. Maximum electrical conductivity was recorded at 6 months of storage (51.11) and minimum (47.85) during the third month

4.3 FIELD PERFORMANCE OF INVIGORATED SEEDS

The seeds invigorated with the selected six methods were evaluated along with seeds whose dormancy have been broken naturally by storage for field performance and the results are presented below.

4.3.1 Field Emergence

The field emergence of the seeds was significantly influenced by different treatments (Table 21) during field study.Seeds extracted from previous rainy season crop, which was stored till next sowing (T_4), recorded maximum field emergence (72.5 per cent). This was on par with seeds,which are extracted at the time of sowing from intact fruits of previous rainy season crop (T_3) with a field emergence 67.50 per cent. Minimum field emergence (37.50 per cent) was recorded by extracted seeds of previous summer season crop, which was stored till next sowing (T_2) and seeds treated with NAA 50 ppm (38.33 per cent).

Table 20. Effect of storage on electrical conductivity of invigorated seeds.

Electrical conductivity (µ mhos/cm)							
Months / Treatments	1MAS	2MAS	3MAS	4MAS	5MAS	6MAS	Mean
T_1	42.65	40.55	41.70	44.10	46.40	46.15	43.59
T_2	41.55	43.20	49.45	51.85	50.65	50.90	47.93
T_3	41.25	40.15	42.55	43.00	42.50	43.50	42.15
T_4	46.10	44.36	37.80	45.25	46.75	48.15	44.72
T_5	31.90	36.75	33.80	35.60	40.40	40.65	36.52
T_6	78.05	70.90	72.00	68.90	72.05	70.55	72.08
T_7	63.90	60.15	57.65	59.00	56.40	57.90	59.17
Mean	49.34	48.00	47.85	49.67	50.74	51.11	

C.D. for months=1.31
C.D. for treatments=1.30
C.D. for treatments within months=3.46

T_1 - GA_3 (25 ppm) for 24 hours.
T_2 - GA_3 (50 ppm) for 24 hours.
T_3 - GA_3 (100 ppm) for 12 hours
T_4 - NAA (25 ppm) for 24 hours
T_5 - NAA (50 ppm) for 24 hours
T_6 - 1 % KNO_3 for 12 hours.
T_7 - Control (untreated seeds)
MAS - months after storage

4.3.2 Length of the Main Vine.

The length of the main vine was found to be non-significant between different treatments (Table 21). However maximum vine length (522.67 cm) was observed in plants raised from intact stored fruits of previous rainy season. Seeds treated with 1 % KNO_3 also produced long (520.33cm) vine. Seeds treated with GA_3 50 ppm produced shortest (419 cm) vine.

4.3.3 Primary Branches per Plant

The number of primary branches per plant was significantly influenced by different treatments (Table 21). The plants raised from extracted and stored seeds of previous summer season crop, produced maximum primary branches of 2.77. The minimum primary branches of 1.73 was noted in plants raised from seeds treated with GA_3 100 ppm. Plants raised from NAA 25 ppm treated seeds and those raised using seeds collected from stored intact fruits of previous summer crop were on par.

4.3.4 Days to First Female Flower Opening

There was significant difference between the treatments for the number of days to first female flower opening (Table 22). The plants raised from seeds treated with NAA 50ppm (T_9) showed earliest flowering at (56.00) days, which was on par with plants raised from GA_3 25 ppm treated seeds (56.33 days). The delayed flowering (63.00 days) was noticed in plants raised from extracted and stored seeds of previous summer season crop (T_2), which was followed by plants raised from GA_3 100 ppm treated seeds (60.33 days).

Table 21. Effect of treatments on field emergence,length of main vine and primary branches per plant

Treatments	Field emergence (%)	Length of the main vine (cm)	Primary branches per plant
T_1	55.00 ^{b}	468.00 ^{a}	1.77 ^{d}
T_2	37.50 ^{d}	396.00^{a}	2.77 ^{a}
T_3	67.50 ^{a}	522.67^{a}	1.96 ^{bcd}
T_4	72.50 ^{a}	460.67^{a}	2.31 ^{abc}
T_5	44.16 ^{cd}	510.67^{a}	2.01 ^{bcd}
T_6	45.00 ^{cd}	419.00^{a}	1.84 ^{cd}
T_7	48.33 ^{bc}	433.33^{a}	1.73 ^{d}
T_8	42.50 ^{cd}	443.33^{a}	1.74^{d}
T_9	38.33 ^{d}	472.33^{a}	2.42 ^{ab}
T_{10}	40.83 ^{cd}	520.33^{a}	2.10 ^{bcd}

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another

Table 22. Effect of seed invigoration on days to first female flower opening and node at which first female flower appeared.

Treatments	Days to first female flower opening	Node at which first female flower appeared
T_1	59.33 ^{bc}	12.75^{a}
T_2	63.00 ^{a}	13.55^{a}
T_3	57.00 ^{bc}	14.43^{a}
T_4	59.00 ^{bc}	13.90^{a}
T_5	56.33 ^{c}	13.25^{a}
T_6	57.33 ^{bc}	13.33^{a}
T_7	60.33 ^{ab}	14.05^{a}
T_8	57.00 ^{bc}	13.19^{a}
T_9	56.00 ^{c}	13.33^{a}
T_{10}	57.33 ^{bc}	13.33^{a}

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another

4.3.5 Node at which First Female Flower Appeared

The node at which first female flower appeared was not significantly influenced by different treatments (Table 22).However the first female flower appeared on the earlier node (12.75) in case of crop raised from intact stored fruits of previous summer season. But in the plants raised from intact stored fruits of previous rainy season, first female flowers appeared on later (14.43) nodes only.

4.3.6 Per cent of Fruit Set

Table 23 shows the effect of different treatments on percentage of fruit set. Percentage of fruit set was not found to be significantly influenced by different treatments. However, seeds treated with GA_3 (100 ppm) recorded the highest per cent (64.44) fruit set while the minimum fruit set was recorded by plants raised from seeds of intact stored fruits of previous summer season crop (37.68)

4.3.7 Days to First Harvest for Vegetable Purpose

There was no significant difference among the treatments in days to first harvest for vegetable purpose (Table 23). However the minimum days for the first vegetable harvest (77 days) were recorded by seeds extracted from intact stored fruits of previous summer and rainy season crop and seeds treated with GA_3 25 ppm. The maximum days (83 days) were recorded by plants raised from seeds treated with GA_3 50 ppm and those raised from stored seeds of previous summer season crop.

4.3.8 Single Fruit Weight

Single fruit weight was not significantly influenced by different treatments (Table 24). However, the maximum single fruit weight (2893.33g) was recorded

Table 23. Effect of seed invigoration on percent fruit set and days to first harvest for vegetable purpose.

Treatments	Per cent fruit set	Days to first harvest (vegetable purpose)
T_1	37.68[a]	77.00[a]
T_2	39.41[a]	83.00[a]
T_3	62.10[a]	77.00[a]
T_4	45.27[a]	81.00[a]
T_5	53.81[a]	77.00[a]
T_6	46.79[a]	83.00[a]
T_7	64.44[a]	79.00[a]
T_8	52.70[a]	81.66[a]
T_9	53.63[a]	79.00[a]
T_{10}	52.22[a]	81.00[a]

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another

by seeds treated with GA_3 25 ppm and minimum weight was shown by seeds treated with GA_3 50 ppm (1733.33g).

4.3.9 Fruits per Plant

The number of fruits obtained per plant when harvested at vegetable stage was significantly different among different treatments(Table 24). The plants raised from extracted seeds of previous rainy season crop (T_4) produced the maximum number of fruits (3.42). Plants raised from KNO_3 treated seeds and those raised from extracted seeds of previous summer season crop produced least number of fruits (1.72 and 1.75 respectively).

4.3.10 Circumference of Fruit at Vegetable Harvest

The data on the effect of treatments on circumference of fruit at vegetable harvest is presented in Table 25. The treatments had no significant influence on the circumference of fruit harvested at vegetable stage. However, seeds treated with GA_3 50 ppm produced fruits with maximum circumference (44 cm) while seeds treated with 1% KNO_3 produced fruits with minimum circumference (37.67cm).

4.3.11 Length of Fruit

Length of fruit at vegetable harvest was not significantly influenced by different treatments (Table 25). However, maximum fruit length (32.75) was recorded by seeds treated with NAA 50 ppm while minimum fruit length (29.17 cm) was recorded in plants raised from seeds treated with GA_3 100 ppm and seeds treated with 1% KNO_3

Table 24. Effect of seed invigoration on single fruit weight and fruits per plant for vegetable purpose.

Treatments	Single fruit weight (kg)	Fruits per plant
T_1	2173.33[a]	2.76 [ab]
T_2	1945.00[a]	1.75 [c]
T_3	2282.00[a]	3.00 [ab]
T_4	2217.33[a]	3.42 [a]
T_5	2893.33[a]	2.57 [b]
T_6	1733.33[a]	2.30 [bc]
T_7	2203.33[a]	2.50 [bc]
T_8	1948.33[a]	2.40 [bc]
T_9	2205.00[a]	2.78 [ab]
T_{10}	1991.00[a]	1.72 [c]

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another

4.3.12 Fruit Shape Index

Fruit shape index at vegetable harvest was not significantly influenced by different treatments (Table 25). However maximum fruit shape index (2.47) was recorded by plants raised from seeds collected from intact stored fruits of previous rainy season crop and the minimum fruit shape index (2.22) was recorded by plants raised from stored extracted seeds of previous summer season crop.

4.3.13 Fruit Yield per Plant

The yield per plant was significantly influenced by different treatments (Table 26). The yield /plant was maximum (4.33Kg) from seeds invigorated with NAA 50 ppm (T_9) which was on par with seeds extracted from intact fruits of previous rainy season crop (T_3,4.31 Kg). This was followed by GA_3 25 ppm treated seeds (T_5) with 3.76 Kg yield per plot. The minimum yield per plot (1.99 Kg) was recorded by seeds extracted from intact fruits of previous summer season crop (T_1), which was on par with GA_3 50ppm treated seeds (2.05 Kg) and seeds treated with NAA 25 ppm (2.09 Kg).

4.3.14 Fruit Yield/ Hectare

The effect of different treatments on fruit yield per hectare is presented in Table 26.The vegetable yield per hectare was highly significant between different treatments.The yield per hectare was maximum (4805.55Kg) from seeds invigorated with NAA 50 ppm (T_9) which was on par with seeds extracted from intact fruits of previous rainy season crop (T_3) (4791.85Kg). This was followed by GA_3 25 ppm treated seeds (T_5) with 4181.48 Kg yield per hectare. The minimum yield per hectare (2207.41 Kg) was recorded by seeds extracted from intact fruits of previous summer season crop (T_1), which was on par with GA_3 50ppm treated seeds (2274.07) and NAA 25 ppm treated seeds (2320.74).

Table 25. Effect of seed invigoration on circumference, length and fruit shape index of fruit for vegetable purpose

Treatments	Circumference of fruit	Length of fruit (cm)	Fruit shape index
T_1	41.00[a]	31.00[a]	2.38[a]
T_2	43.00[a]	30.00[a]	2.22[a]
T_3	38.00[a]	29.83[a]	2.47[a]
T_4	41.17[a]	29.67[a]	2.27[a]
T_5	40.44[a]	30.00[a]	2.33[a]
T_6	44.00[a]	31.33[a]	2.28[a]
T_7	39.83[a]	29.17[a]	2.30[a]
T_8	39.50[a]	30.00[a]	2.43[a]
T_9	43.33[a]	32.75[a]	2.38[a]
T_{10}	37.67[a]	29.17[a]	2.41[a]

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another

Table 26. Effect of seed invigoration on fruit yield per plant and fruit yield per hectare for vegetable purpose.

Treatments	Fruit yield per plant (Kg)	Yield per ha (Kg)
T_1	1.99^{c}	2207.41^{c}
T_2	2.29^{bc}	2520.35^{bc}
T_3	4.31^{a}	4791.85^{a}
T_4	2.96^{abc}	3287.78^{abc}
T_5	3.76^{ab}	4181.48^{ab}
T_6	2.05^{c}	2274.07^{c}
T_7	3.38^{abc}	3759.26^{abc}
T_8	2.09^{c}	2320.74^{c}
T_9	4.33^{a}	4805.55^{a}
T_{10}	2.54^{bc}	2820.37^{bc}

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another.

4.3.15 Days to First Harvest for Seed Purpose.

The fruits of all plants were harvested simultaneously at one hundred and ten days after sowing.

4.3.16 Single Fruit Weight at Seed Harvest

Weight of the single fruit harvested for seed purpose was not significantly influenced by different treatments (Table 27). However, the maximum single fruit weight (5550g) was recorded by plants raised from seeds treated with GA_3 50 ppm and minimum single fruit weight (3520g) was recorded by plants raised from seeds treated with 1% KNO_3.

4.3.17 Fruits per Plant at Seed Harvest

The number of fruits obtained per plant, retained for seed purpose was significantly influenced by different treatments (Table 27).Plants raised from extracted seeds of previous rainy season crop (T_4) produced maximum number of fruits per plant (4.33). All other treatments behaved similarly with least number of fruits (1.22), being produced by plants from extracted seeds of previous summer season crop (T_2).

4.3.18 Circumference of Fruit at Seed Harvest

Circumference of the fruits harvested for seed purpose was significantly influenced by different treatments (Table 28). The plants raised from seeds treated with GA_3 50 ppm (T_6) recorded fruit with maximum circumference of 68cm. The fruits with least circumference (51.94) was recorded by plants raised from extracted and stored seeds of previous summer season crop (T_2).

Table 27. Effect of seed invigoration on single fruit weight and fruits per plant for seed purpose

Treatments	Single fruit weight (g)	Fruits per plant
T_1	4560.00[a]	1.93 [b]
T_2	3630.00[a]	1.22 [b]
T_3	4841.67[a]	2.02 [b]
T_4	3764.67[a]	4.33 [a]
T_5	4443.33[a]	1.47 [b]
T_6	5550.00[a]	1.72 [b]
T_7	3703.33[a]	2.00 [b]
T_8	4980.00[a]	2.28 [b]
T_9	4840.00[a]	1.67 [b]
T_{10}	3520.00[a]	1.55 [b]

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another.

4.3.19 Length of Fruit at Seed Harvest

Length of the fruit harvested for seed purpose was not significantly influenced by different treatments (Table28).Even then maximum fruit length (45.22cm) was recorded by plants raised from extracted and stored seeds collected from previous rainy season crop while minimum length (34.83)was recorded by seeds treated with GA_3 100 ppm.

4.3.20 Fruit Shape Index

The treatments had no significant influence on fruit shape index (Table 28).

However, the fruits of plants raised from seeds treated with KNO_3 showed the highest value (2.49) and seeds treated with GA_3 50 and 100 ppm recorded the minimum value (1.87).

4.3.21 Fruit Yield per Plant

The treatments had significant influence on fruit yield per plant, when harvested at seed maturity (Table 29).The fruit yield per plant, when harvested for seed purpose, was maximum (10.22 kg) from extracted and stored seeds of previous rainy season crop (T_4) which was on par with seeds treated with GA 50 ppm (9.60 Kg). Seeds which were extracted from previous summer season crop and stored till next sowing (T_2) produced the minimum yield per plant (1.67 Kg).

4.3.22 Fruit Yield per Hectare

The effect of treatments on fruit yield per hectare is presented in Table 29.The fruit yield per hectare, when harvested for seed purpose, was maximum (11359.26 Kg) from extracted seeds of previous rainy season crop which was on par with seeds treated with GA 50 ppm (10803.7 Kg.). Seeds, which were

Table 28. Effect of seed invigoration on circumference, length and fruit shape index of fruits for seed purpose

Treatments	Circumference of fruit	Length of fruit (cm)	Fruit shape index
T_1	53.16 ^{bc}	37.16^{a}	2.16^{a}
T_2	51.94 ^{c}	34.94^{a}	2.03^{a}
T_3	61.94 ^{ab}	37.50^{a}	1.89^{a}
T_4	55.11 ^{bc}	45.22^{a}	2.01^{a}
T_5	53.28 ^{bc}	35.83^{a}	2.07^{a}
T_6	68.00 ^{a}	42.00^{a}	1.87^{a}
T_7	55.55 ^{bc}	34.83^{a}	1.87^{a}
T_8	58.83 ^{abc}	36.67^{a}	1.90^{a}
T_9	62.83 ^{ab}	39.16^{a}	2.12^{a}
T_{10}	56.05 ^{bc}	36.39^{a}	2.49^{a}

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another.

Table 29. Effect of seed invigoration on fruit yield per plant and on per hectare basis for seed purpose.

Treatments	Fruit yield/plant (Kg)	Yield/ha (Kg)
T_1	4.60^{bc}	5105.55^{bc}
T_2	1.67^{d}	1859.26^{d}
T_3	4.67^{bc}	5188.89^{bc}
T_4	10.22^{a}	11359.26^{a}
T_5	4.14^{bc}	4600.00^{bc}
T_6	9.50^{a}	10803.70^{a}
T_7	2.42^{bcd}	3796.30^{bcd}
T_8	2.96^{cd}	3288.89^{cd}
T_9	5.54^{b}	6155.56^{b}
T_{10}	2.90^{cd}	3218.52^{cd}

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2-Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop. which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another.

extracted from previous summer season crop and stored till next sowing produced the minimum yield per hectare (1859.26 Kg.)

4.3.23 Seeds per Fruit

The number of seeds per fruit was not significantly influenced by different treatments (Table 30).However maximum seeds (217.33) were present in fruits produced by plants from seeds treated with GA_3 50 ppm, where as the minimum seeds (80.50) were recorded in fruits of plants raised from extracted and stored seeds of previous summer season.

4.3.24 Hundred Seed Weight

The data on the effect of different treatments on hundred seed weight is presented in Table 30.The hundred seed weight was not significantly influenced by different treatments. However the plants raised from extracted and stored seeds of previous rainy season crop recorded the highest hundred seed weight (6.35). The minimum value (4.56) was recorded by plants raised from extracted and stored seeds of previous summer season crop.

4.3.25 Seed Yield per Plot

The seed yield per plot was significantly influenced by the treatments as shown in Table 30.Seeds extracted from previous rainy season crop had maximum seed yield (225.69g). This was followed by seeds treated with GA_3 50 ppm which was on par with all other treatments.

Table 30. Effect of seed invigoration on number of seeds per fruit and hundred seed weight.

Treatment	Seeds/fruit	Hundred seed weight(g)	Seed yield per plot (g)
T_1	111.50[a]	5.55[a]	47.93 (6.94)[b]
T_2	80.50[a]	4.56[a]	18.4 (4.19)[b]
T_3	203.25[a]	4.70[a]	79.10 (8.56)[b]
T_4	210.17[a]	6.35[a]	225.69 (14.90)[a]
T_5	170.00[a]	4.86[a]	53.58 (6.50)[b]
T_6	217.33[a]	5.86[a]	83.76 (8.33)[b]
T_7	143.67[a]	5.07[a]	85.56 (7.33)[b]
T_8	163.33[a]	6.27[a]	72.41 (8.33)[b]
T_9	197.00[a]	5.36[a]	68.36 (8.29)[b]
T_{10}	126.67[a]	5.54[a]	63.78 (7.88)[b]

T_1- Storage of intact fruits from previous summer crop and seeds extracted at the time of sowing.
T_2- Extracted seeds from previous summer season crop, which is stored till sowing.
T_3- Storage of intact fruits from previous rainy season crop and seeds extracted at the time of sowing.
T_4- Extracted seeds from previous rainy season crop, which is stored till sowing
T_5- Seeds treated with GA_3 (25 ppm) for 24 hours.
T_6- Seeds treated with GA_3 (50 ppm) for 24 hours
T_7- Seeds treated with GA_3 (100 ppm) for 12 hours
T_8- Seeds treated with NAA (25 ppm) for 24 hours
T_9- Seeds treated with NAA (50 ppm) for 24 hours
T_{10}- Seeds treated with 1 % KNO_3 for 12 hours
Values having common superscript are not significantly different from one another.
Figures in parenthesis are square root transformed values.

4.4 EVALUATION OF SEEDS EXTRACTED FROM THE FIELD STUDY

Table 31 shows the performance of seeds which were extracted from fruits of field study. The seeds extracted from fruits collected from the field study showed significant difference for different seed quality parameters.

4.4.1 Germination Percentage

Maximum germination was recorded by seeds treated with GA_3 25 ppm (66.00), which was on par with seeds treated with NAA 50 ppm (64.00) . Minimum germination was recorded by seeds collected from the crop raised from extracted and stored seeds of previous summer crop (6.00%)

4.4.2 Speed of Germination

The highest speed of germination (11.81) was recorded by seeds collected from the fruits of crop raised from the intact stored fruit of previous rainy season crop which was followed by seeds treated with NAA 25 ppm (10.38). Seeds collected from plants of previous summer season crop (T_2) recorded the minimum (0.69) speed of germination.

4.4.3 Vigour Index- I of the Seedling

The seeds collected from plants raised from seeds treated with NAA 25 ppm and 50 ppm had highest vigour index I (1298 and 1239) respectively. The lowest vigour index I value was shown by T_2 (65.00).

Table 31. Evaluation of the seeds extracted from the field study

Treatment	Germination %	Speed of germination	Vigour index I
T_1	38.00^{bc}	5.202^{cd}	682^{cd}
T_2	6.00^{d}	0.69^{e}	65^{e}
T_3	58.00^{ab}	11.81^{a}	1106^{abc}
T_4	54.00^{ab}	8.22^{abc}	1151^{abc}
T_5	66.09^{a}	10.22^{ab}	1189^{ab}
T_6	38.00^{bc}	6.23^{bcd}	717^{bcd}
T_7	16.00^{cd}	2.69^{de}	303^{de}
T_8	62.00^{ab}	10.38^{ab}	1298^{a}
T_9	64.00^{a}	9.98^{ab}	12.39^{a}
T_{10}	24.00^{cd}	3.98^{cde}	486.00^{de}

T_1: Seeds collected from the fruits of crop raised from the intact fruit of previous summer season crop.
T_2: Seeds collected from the fruits of crop raised from seeds of previous summer season crop.
T_3: Seeds collected from the fruits of crop raised from the intact fruit of previous rainy season crop.
T_4: Seeds collected from the fruits of crop raised from seeds of previous rainy season crop.
T_5: Seeds collected from the fruits of crop raised from seeds invigorated with GA_3 25 ppm
T_6: Seeds collected from the fruits of crop raised from seeds invigorated with GA_3 50 ppm.
T_7: Seeds collected from the fruits of crop raised from seeds invigorated with GA_3 100 ppm.
T_8: Seeds collected from the fruits of crop raised from seeds invigorated with NAA 25 ppm
T_9: Seeds collected from the fruits of crop raised from seeds invigorated with NAA 50 ppm
T_{10}: Seeds collected from the fruits of crop raised from seeds invigorated with 1 % KNO_3
Values having common superscript are not significantly different from one another

Plate 5. Performance of seeds extracted from field crop

Discussion

5. DISCUSSION

The present investigation was carried out at Department of Olericulture, College of Horticulture, Vellanikkara to standardize seed invigoration treatments for breaking dormancy in fresh ash gourd seeds and to study the storage potential of invigorated seeds along with field performance. The results of the study are discussed here with.

5.1 SEED INVIGORATION TO BREAK DORMANCY

Freshly extracted ash gourd seeds do not give the required minimum germination of 60 per cent. An after ripening period of three months is necessary to get satisfactory germination (Kannath, 1996). The influence of various invigoration treatments on the freshly extracted ash gourd seeds was studied at monthly intervals upto six months. Different acids and growth regulators were used for seed invigoration at varying concentrations along with water treatment. To evaluate the dormancy behaviour in fresh seeds, the two parameters of dormancy, like intensity and days to achieve 60 per cent germination were assessed. Along with these parameters other seed quality parameters like germination per cent, speed of germination, root length, shoot length ,seedling dry weight, vigour index I and II were also evaluated.

None of the treatments could give a gradual release of dormancy during the period of study. Intensity of dormancy at five and ten days after sowing showed varying values at different months. If any treatment is to be effective in breaking dormancy, it should have a decreased intensity of dormancy than the control. Regarding the intensity at five days of sowing (NGS_5), seeds soaked in cold water and treated with GA_3 50 ppm, 100 ppm and KNO_3 were always superior to control except at 0 month after extraction giving a lower or equal intensity of dormancy. But when the intensity was recorded at ten days after sowing, all the treatments except NAA 50 ppm were inferior to control at 1 MAE.

Except at this month, seed treatments with GA_3 25, 50, and 100 and KNO_3 were superior to control indicating efficiency in breaking dormancy. Though effective in the initial days, water soaked seeds did not give good results at ten days after sowing.

There was no gradual release of dormancy from 0 to 5 MAE, since the experiments were conducted at different months using different seed lots. But in seeds treated with GA_3 50 ppm, there was gradual release of dormancy from 65.33 at 0 MAE to 26 at 5 MAE. Regarding untreated seeds, there was a sudden release of dormancy at 1 MAE giving intensity of 47.62 and the induction of dormancy at 2 MAE and then a gradual release was noticed from 2 MAE onwards (Table 1.b).

The days to achieve 60 per cent germination was comparatively low (2.33 days) in seeds treated with NAA 25 ppm at 5 MAE i.e. NAA 25 ppm was very fast in attaining the minimum germination, where as GA_3 50 ppm, took maximum days (6.67) to attain minimum germination. Untreated seeds never gave minimum germination requirement even after completion of experiment.

Different seed quality parameters were significantly influenced by seed invigoration treatments. Considering the germination per cent, none of the invigoration treatments could give more than 60 per cent germination, which is the required minimum germination in cucurbits, immediately after extraction (0MAE). However, at 0MAE maximum germination per cent was recorded by seeds treated with 5 N HNO_3 for 20 minutes (44.67). Acid scarification with HNO_3 has been found to be effective in breaking dormancy of bitter gourd seeds as reported by Singh and Singh (1969). During 1 MAE, only seeds treated with NAA 50 ppm (70.48) could give the minimum required germination per cent. At 2 MAE seeds treated with GA_3 25 ppm, NAA 50 ppm and 1 % KNO_3 could give more than the minimum required germination per cent. Similar findings of increased germination per cent using 1 % KNO_3 was reported by Renugadevi and

Selvaraj (1994) in bitter gourd. The superiority of KNO_3 may be ascribed to its role in making less oxygen available for the citric acid cycle and thereby enhancing the ambient oxygen level. At 3 MAE, GA_3 50 ppm was effective in giving the required minimum germination per cent (64.76). Seeds treated with 5N H_2SO_4 , GA_3 25, 50 and 100 ppm, NAA 25 ppm and 1 % KNO3 could give a germination percent of more than 60 per cent both during 4 and 5 MAE. Though the seeds treated with NAA 50 ppm improved the germination during initial period, the effect could not be retained throughout the period of study. Untreated seeds gave a germination of 28 per cent immediately after extraction, which was increased only to 56.33 per cent at 5 MAE. Untreated seeds did not attain the required germination even after five months of storage. Seeds soaked in water, whether hot or cold could give more than 60 per cent germination till 4 MAE. At 5 MAE, cold water soaking resulted in more than 60 per cent germination. These treatments could not result in maximum germination during the initial months.

Though, germination could be improved by different invigoration treatments but none of the treatments exhibited a steady superior performance during the entire period of study. The beneficial effects of seed invigoration using GA_3 were reported earlier in tomato (Choudhury and Singh, 1960), in okra by Srivastava and Singh (1968) and by Pal *et al.* (1970). In okra Sadawarte and Gupta (1968) observed increased percentage of germination in brinjal seeds by presowing soaking with IAA and NAA each at 5 and 10 ppm.

Seeds treated with 5 N HNO_3 showed higher speed of germination (8.66) in freshly extracted seeds. Seeds treated with GA_3 100ppm showed maximum speed during 1 MAE (14.29), NAA 50 ppm (13.23) at 2MAE, GA 50 ppm and NAA 25 ppm during 3 MAE, GA_3 100ppm at 4 MAE (14.35) and GA_3 25 ppm during 5 MAE (18.45).

The seeds treated with 5 N HNO_3 and NAA 25 ppm exhibited the maximum vigour index I in freshly extracted seeds (0MAE). Seed treated with

NAA (50 ppm) showed higher vigour index I during 1 and 2 MAE.GA_3 25 ppm also resulted in higher vigour index during 2 MAE. GA_3 50 ppm could result in increased vigour index I during 3 and 5 MAE and GA_3 100 ppm during 4MAE. An increased vigour has been reported by seed treatment with GA_3 100 ppm in bellary onion (Vanangamudi *et al.*, 1988). Seed treatment with H_2SO_4 and HCl always exhibited poor vigour index I, which was even inferior to untreated seeds. Only during 5 MAE H_2SO_4 gave a slightly better performance.

Seedling dry weight was significantly influenced at 0MAE and 3 MAE only. GA_3 100 ppm recorded maximum seedling dry weight during both these months. In vigour index II, seeds behaved differently with various treatments during the period of study. Seeds treated with 5 N HNO_3 produced higher vigour index II (3.88) in freshly extracted seeds. Seeds treated with NAA 50 ppm gave maximum vigour index II during 1and 2 MAE where as NAA at lower concentration of 25 ppm resulted in maximum vigour index II during 3 and 4 MAE.

Results of the monthly evaluation of seed invigoration treatments varied significantly during each month. But none of the treatments could maintain the superiority, through out the period of experimentation. The differential performance was due to the difference in seed lot and seasonal influence.

Overall performance was analysed to select the best five invigoration treatments which could give the overall better seedling performance. Important seed quality parameters like germination per cent, speed of germination, vigour index I and vigour index II were only considered for overall performance (Fig. 1-4)

Seeds treated with GA_3 50 ppm resulted in maximum germination per cent (55.08) (Fig 1) and vigour index I (1003)(Fig 3). Similar results were reported earlier by Vaish *et al.* (1998) who found that seed treatment with GA_3 50

Overall performance of invigorated seeds

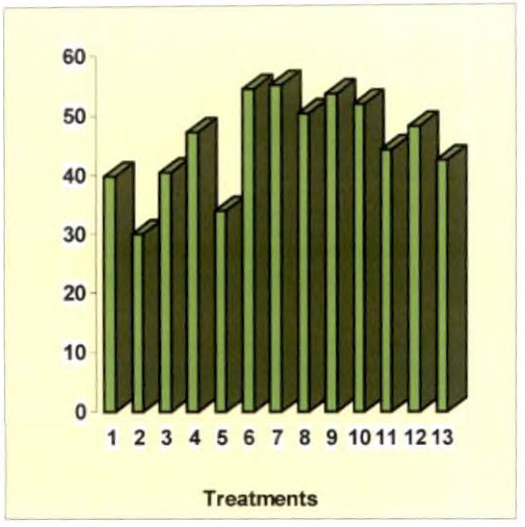

Fig 1. Germination percent

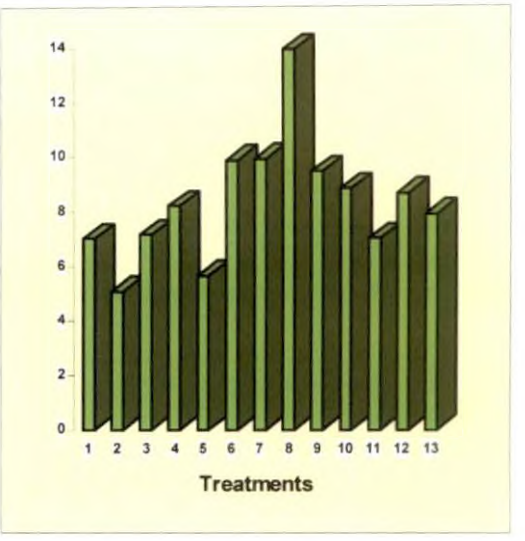

Fig 2. Speed of germination

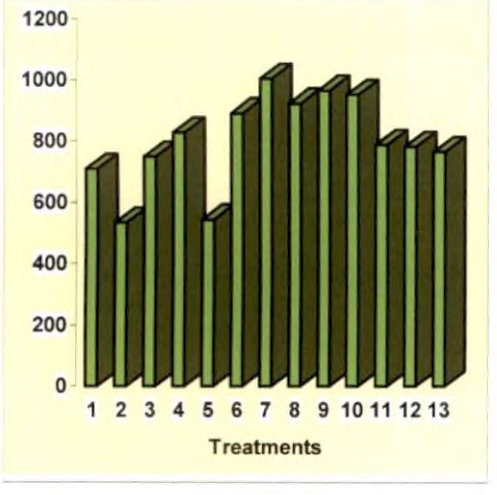

Fig 3. Vigour index I

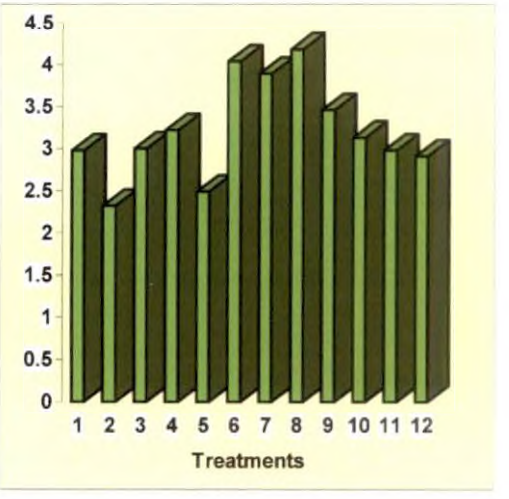

Fig 4. Vigour index II

ppm gave superior germination and vigour index I in brinjal c.v. Azad hybrid. GA_3 100ppm resulted in maximum speed of germination (13.94) (Fig 2). Seeds invigorated with NAA 25 ppm gave maximum vigour index I (964) and II (4.18) .GA_3 25 ppm also gave a better germination per cent and vigour index I. NAA at 100 ppm always recorded an inferior performance. GA_3 was effective at all the concentrations tried. But NAA was effective at lower concentration of 25 and 50 ppm. Sadawarte and Gupta (1968) found that only lower concentrations of NAA were effective in increasing the emergence of brinjal seedlings.GA_3 was comparitively better in seed invigoration than NAA.The dormancy breaking effect of GA_3 was reported by Suryawanshi *et al.*(1996) in *Cucumis sativus* c.v.Himangi and by Yogeesha *et al.*(2002) in brinjal variety Arka Neelkant.

Seed treatment with water, either cold or hot, was found to be ineffective and thereby producing seedlings with poor performance. Though acid treatments were found to be superior during some months, the analysis of overall performance revealed that they were inferior. Thus from the present study it is clear that scarification do not have a significant role in breaking dormancy of fresh ashgourd seeds. Singh and Singh (1969) reported that dormancy in bittergourd can be broken by acid scarification of seeds with dilute H_2SO_4 , HNO_3 or HCl for 30- 60 minutes. Ashgourd seeds have a soft seed coat compared to that of bitter gourd. Acid scarification or water soaking might have damaged the soft seed coat, resulting in damage of seed and there by producing seedlings of inferior quality. Since the growth regulators had given a superior performance, and the scarification treatments had not given any effect, the dormancy in ashgourd can be considered as endogenous in nature.

The present study reveals that the failure of fresh ashgourd seeds to germinate may be attributed to chemical block and not due to physical blocks. Such chemical blocks are caused either by the presence of growth inhibiting chemicals or might have resulted from a deficiency of some essential compound.(Bewley and Black, 1982). Such blocks in ash gourd might have been

removed by application of growth regulators.These artificially applied growth regulators interact with environmental conditions like light and temperature and thus germination appears to proceed by an alternate pathway. (Desai *et al.*1997)

If the effect of treatments and storage are together considered, it can be seen that there is no effect of invigoration immediately after seed extraction. Seed quality parameters are improved during the final stage of experimentation only. Thus it can be stated that fresh ash gourd seeds require an after ripening to break the dormancy. After ripening may permit the accumulation of the missing growth promoter to a level permitting germination (Desai *et al*,1997). If such after ripened seeds are treated using growth regulators invigoration can be effective.

Based on the analysis of the overall performance the best five treatments GA_3 25,50,100 ppm NAA 25 and 50 ppm were selected. Beneficial effects of seed invigoration with KNO_3 were reported by Solanki and Joshi (1984) in onion, Renugadevi (1992) in ash gourd, Singh *et al.* (1999) in musk melon and by Ganar (2003) in ashgourd. Since number of references indicating the beneficial effects of KNO_3 were obtained, KNO_3 was also included for further studies though it performed poor in the present study.

5.2 STORAGE POTENTIAL OF INVIGORATED SEEDS

Fresh ash gourd seeds invigorated with the best six treatments, selected from the initial evaluation were subjected to a storage study to evaluate the storage potential of invigorated seeds. Seeds were given an after ripening period of two months, invigorated with the chemicals and then stored for a period of six months. Intensity and duration of dormancy, germination per cent, speed of germination, root length, shoot length, vigour index I and II and electrical conductivity were evaluated at monthly intervals.

Germination percentage gradually reduced during storage exhibiting a germination of 87.81 per cent at one month after storage (MAS) to 59.26 at 6 MAS (Fig.6). Though it showed a gradual reduction, the germination could be maintained above the minimum requirement (60.00) even at 5MAS. Suryanarayana and Arifuddin (1980) reported that storage of treated seeds gave good percentage of germination upto 15 to 30 days in okra. Germination percentage of invigorated seeds recorded in item 5.1 and 5.2 showed variation, which may be due to the seasonal influence. The initial invigoration studies were conducted during rainy season, whereas the storage studies were done during summer season.

Considering the effect of invigoration treatment when averaged over months, all the treatments except GA_3 25 ppm showed enhanced germination per cent when compared with untreated seeds (Fig.5). Thus the invigorated seeds can be stored for a period of five months without loss of viability. Beneficial effects of different seed invigoration treatments on storage of seeds were reported using different chemicals by Rudrapal and Basu (1980) in mungbean using iodine and by Woodstock *et al.* (1983) in onion, pepper and parsley by using butylated hydroxytoluene.

There was a gradual reduction in the speed of germination and vigour index I during the period of storage. Speed of germination gradually reduced from 15.23 at 1MAS to 10.50 at 6 MAS (Fig. 8). Similarly vigour index I was gradually reduced from 1505 at 1MAS to 987 at 6MAS(Fig. 10). But in vigour index II (Fig. 12) and seedling dry weight, a slight increase was noticed at 2 and 4 MAS which was then gradually reduced at 6 MAS. Gill and Delouche (1973) reported rate of germination and seedling growth as the most consistent and sensitive measures of the progress of deterioration in corn. In the present study there was an overall decrease in the germination per cent, speed of germination and vigour index I during storage. Kannath (1996) reported similar results in ash gourd during storage.

Performance of invigorated seeds during storage

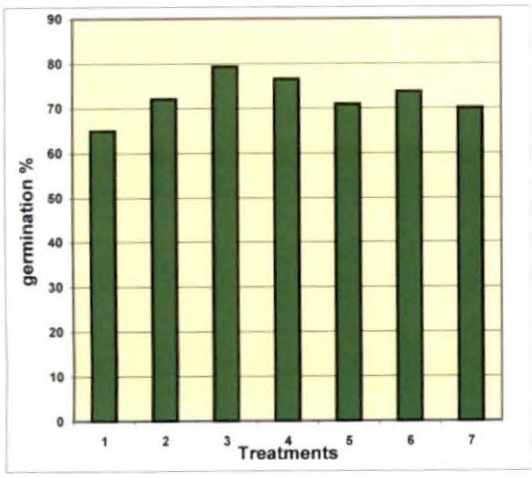

Fig 5. Effect of treatments on germination per cent

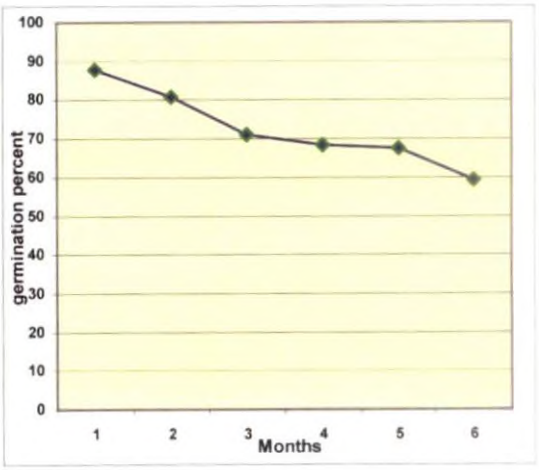

Fig 6. Germination percent at monthly intervals

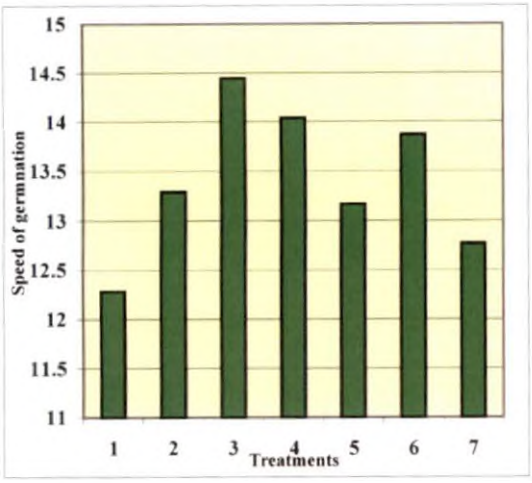

Fig 7. Effect of treatments on speed of germination

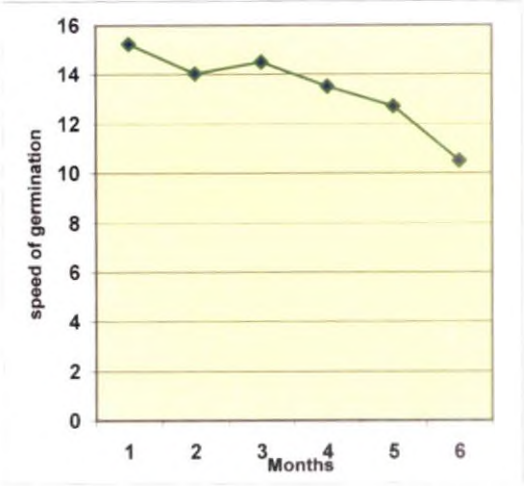

Fig 8. Speed of germination at monthly interval

Considering the treatments, all invigoration treatments except GA_3 25 ppm exhibited superior performance with respect to the various seed quality parameters. In the intensity of dormancy, GA_3 25 ppm treated seeds exhibited highest intensity of dormancy (35.11) and a germination per cent of 64.89 which is lower than the untreated seeds. Untreated seeds recorded a mean dormancy of 29.11 and germination of 70.00 per cent. Seeds invigorated with GA_3 25 ppm had lower germination per cent (Fig 5), speed of germination (Fig 7) and vigour index I (Fig 9) compared to untreated seeds. Hence seeds treated with GA_3 25 ppm cannot be stored. Though no reference related to the effect of seed invigoration using growth regulators on storage of seeds has been reported, seed treatment with other chemicals for maintaing viability and vigour was reported by many workers like Waller *et al* (1960) in cucumber and squash, Macias *et al* (1969) and Buydoso (1979) in cucumber, Chandrasekharan (1979) in bottle gourd, Krishnaprasad (1980) and Renugadevi (1992) in ash gourd.

Electrical conductivity of seeds treated with KNO_3 was high and all other seed quality parameters were found to be low during all the months (Fig. 13). This clearly indicates the seeds invigorated with KNO_3 cannot be stored. Pesis (1983) reported that electrolytic leakage is not a suitable test for seed quality in muskmelon. When a seed is said to be deteriorated in storage, it should have low germination per cent, vigour and a high electrical conductivity. But in the present study all the seed quality parameters except electrical conductivity, showed a gradual reduction, where as in electrical conductivity, there was no such gradual increase. No apparent correlation could be obtained with seed leachate electrical conductivity and seed quality. So it cannot be taken as a suitable test for seed quality in ash gourd. This was in accordance with the reports of Kannath (1996) in ash gourd.

Invigorated seeds except with GA_3 25 ppm can be safely stored for a period of 5 months. Chauhan *et al.* (1984) found that leaching of toxic metabolites, germination advancement, antipathogenic effect, repair of

Performance of invigorated seeds during storage

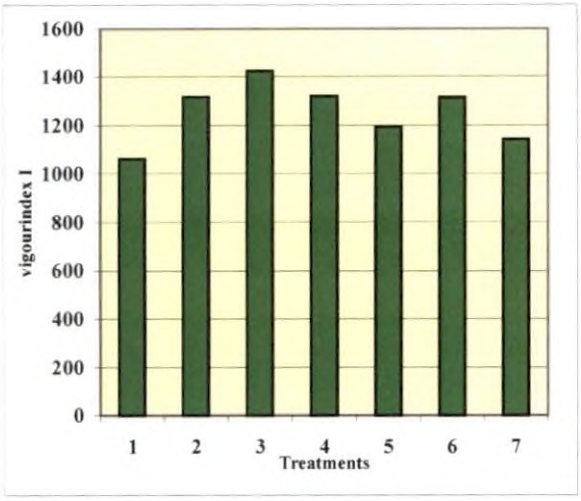

Fig 9. Effect of treatments on vigour index I

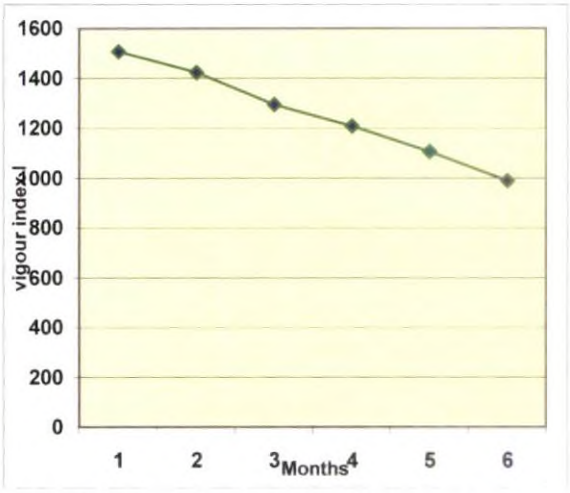

Fig 10. Vigour index I at monthly intervals

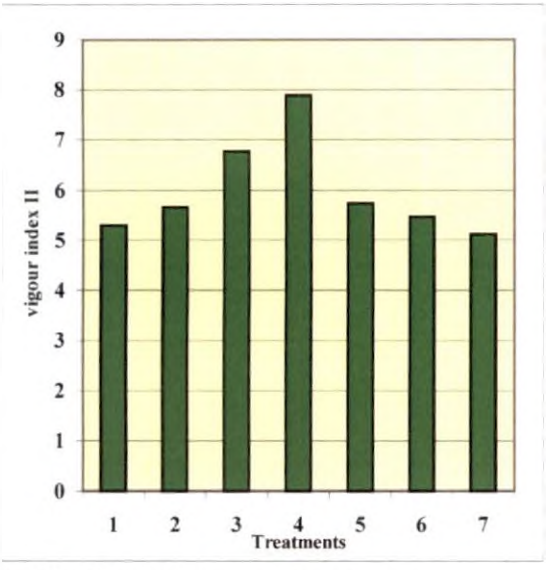

Fig 11. Effect of treatment on vigour index II

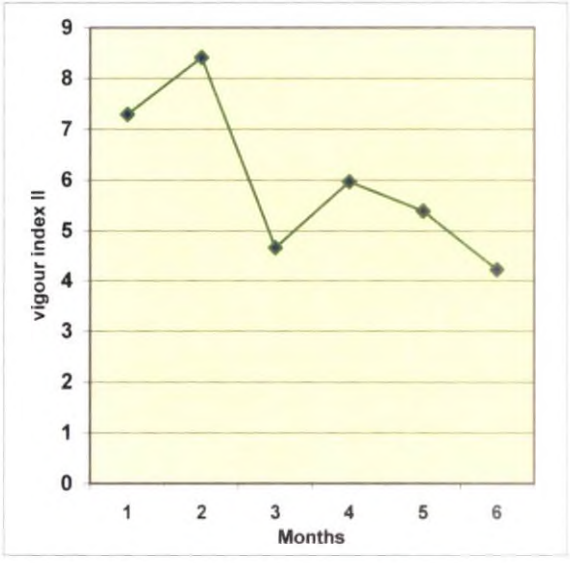

Fig 12. Vigour index II at monthly intervals

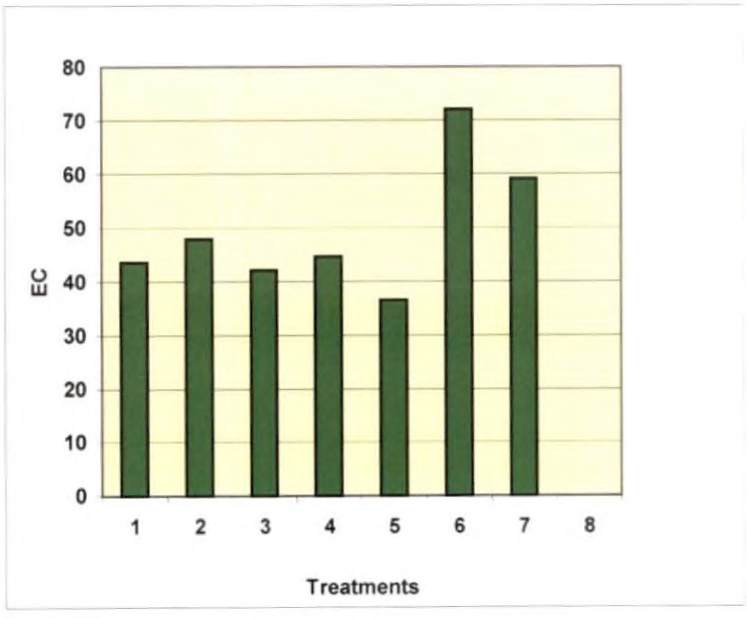

Fig 13. Effects of treatment on electrical conductivity

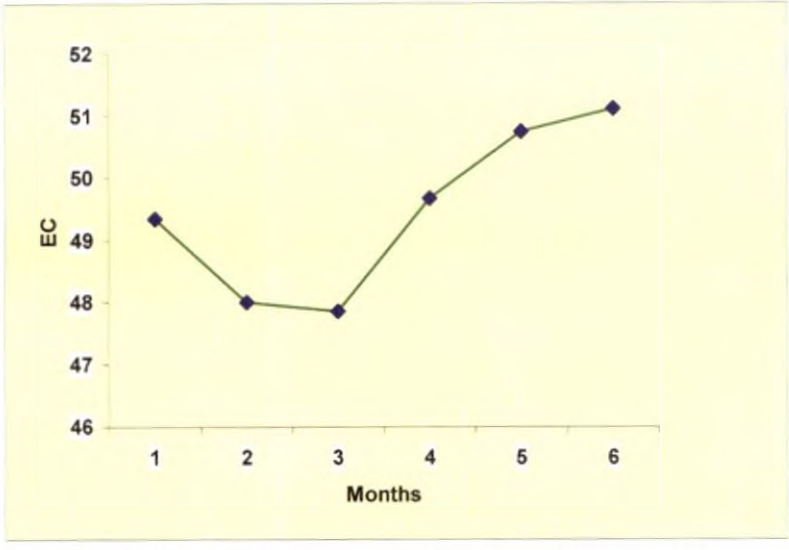

Fig. 14. Electrical conductivity at monthly intervals

biochemical lesions, quinching and counteraction of free radicals, prevention of lipid peroxidation etc.could be the probable reasons to reduce the rate of deterioration of invigorated seeds during storage. Such invigorated seeds can be supplied to the farmers for immediate use. But the effect of prolonged storage is to be studied in detail.

5.3 FIELD PERFORMANCE OF INVIGORATED SEEDS

The freshly extracted seeds of ashgourd were invigorated with the best six treatments selected during the initial study and their field performance was compared with certain traditional farmer's practices. Seeds whose dormancy have been broken naturally by giving after ripening were compared. The seeds were collected from the previous summer and rainy season crop and included in the field study. The fruits were stored as such and seeds were extracted at the time of sowing in one treatment and in other treatments, the extracted seeds were stored till next sowing.

Only certain limited characters like field emergence, number of primary branches, days to first female flowering, number of fruits per plant, fruit yield and seed yield were significantly influenced by the treatments. Circumference of the fruit was significantly influenced only when it is harvested for seed purpose. Characters like length of main vine, node at which first female flower appeared, per cent fruit set, single fruit weight, circumference of fruit, length of fruit, fruit shape index, seeds per fruit and 100 seed weight did not show any significant difference due to treatments.

Crops raised using seeds of previous rainy season showed good field emergence. Both the seeds which were extracted and stored and those extracted from the intact fruits at the time of field sowing recorded the highest field emergence (72.5 and 67.5 respectively). These two treatments could get a storage and after ripening period of about 3 months. This period of post harvest ripening

might be beneficial for breaking dormancy and improving the emergence. Similar trends have been reported by Odland (1937) in cucurbits, by Holmes (1953) in squashes, by Quagliotli *et. al* (1981) in chilli, Araujo *et al.* (1982) in cucurbits, Nagy (1987) in *Cucurbita pepo*, Krishnaswamy (1991) in bitter gourd and Gowda and Ramegowd (1996) in cucumber and Kannath (1996) and in ashgourd. The minimum field emergence (37.50) was recorded by seeds extracted from previous summer season crop and those treated with NAA 50 ppm (38.33). The seeds from previous summer season had a long storage period of one year. Mini *et al.* (2002) reported that seeds of ashgourd showed a gradual reduction in germination during open storage reaching to less than 60 per cent at nine months of storage. In the present study, growth regulators in general did not result in superior emergence. However higher percentage of field emergence by using growth regulators was reported by Choudhury and Singh (1960) in tomato, Srivastava and Singh (1968) and Pal *et al.* (1970) in okra and Singh *et al.*(1973) in bottle gourd, bittergourd, watermelon and okra.

The seeds extracted from previous summer season crop produced maximum number of primary branches (2.77), which was closely followed by NAA 50 ppm (2.42). Maclure and Gulifoyle (1989) observed that accelerated activity of auxin in plant induces primordial growth leading to more of vegetative growth. A negative relation between field emergence and the number of primary branches were obtained.

Seeds treated with NAA 50 ppm and GA_3 25 ppm showed early flowering (56.00 and 56.33 days respectively). Adulka and Verma (1965) and Even (1970) found that seeds soaked in GA_3 50 ppm induced early flowering in tomato and brinjal respectively. Seeds extracted from fruits of previous summer season crop took maximum number of days to flowering (63 days). Higher the number of primary branches the more the vegetative growth, inducing late flowering in ashgourd.

Though,per cent fruit set and single fruit weight were not significantly different, the number of fruits per plant and fruit yield were different when harvested for vegetable purpose. The fruit yield per plant for vegetable purpose was maximum for seeds treated with NAA 50 ppm (4.33 kg) and seeds extracted from intact fruits of previous rainy season crop (4.31). Since the yield of the crop per hectare was calculated from yield per plant, the significant difference between treatments remained same. Thus highest fruit yield per hectare was obtained from seeds treated with NAA 50 ppm (4805.55 kg) and seeds extracted and stored from intact fruits of previous rainy season crop (4791.85). Maximum number of fruits per plant for vegetable purpose was reported by seeds extracted and stored from previous rainy season (3.42) crop which was closely followed be seeds extracted from intact fruits of previous rainy season crop (3.00). NAA 50 ppm also produced higher (2.78) fruit number.

Though not significant, single fruit weight when harvested for vegetable purpose was maximum for seeds treated with GA_3 25 ppm (2893.33) which was closely followed by seeds extracted from intact fruits of previous rainy season crop (2282), seeds collected and stored from previous rainy season crop (2217.33), seeds treated with NAA 50 ppm (2205) and GA_3 100 ppm (2203.33). The results revealed the superiority of after ripening in influencing the yield of the crop. Collecting seeds from the intact fruits of previous rainy season crop was found to be superior, in increasing vegetable yield. However, among the growth regulators NAA 50 ppm was found to have a promising effect. In addition to producing maximum number of fruits, seeds treated with NAA 50 ppm recorded higher number of primary branches (2.42) and maximum fruit length (32.75). NAA 25 ppm (17.30) also recorded a superior yield. In sponge gourd, Abusaleha and Dutta (1991) observed that yield per vine was positively correlated with fruits per vine, fruit length and branches per vine. The factors like primary branches and fruit length might have influenced in increasing the yield of ash gourd. The effect of growth regulators on crop yield was reported by Choudhury and Singh (1960) in tomato ,Singh and Dohare (1964) in radish, Pal *et al* (1970) in okra and

Sadawarte and Gupta (1968) in brinjal. Since auxins at higher concentration induces femaleness, it might have increased the fruit yield. The auxin is found to direct transport of nutrients, hormones and photo synthetase and favours increased fruit set by their application(Krishnamoorthi,1981).Thus, among growth regulators NAA 50 ppm is found to increase vegetable yield in ashgourd.

When harvesting was done for seed purpose,the seeds extracted and stored from previous rainy season and those treated with GA_3 50 ppm gave maximum yield (10.22 and 9.60 kg respectively). Sadawarte and Gupta (1968) reported that yield of brinjal plants of Pusa Purple Long variety can be almost doubled by soaking the seeds in GA_3 40 ppm. Similar reports of beneficial effect of GA_3 were reported by Choudhry and Singh (1960) in tomato and by Pal *et al.* (1970) in okra. Seeds extracted and stored from the previous rainy season crop gave maximum number of fruits per plant (4.33). Seeds treated with GA_3 50 ppm exhibited highest circumference (68 cm) and maximum length (42cm) resulting in higher fruit size, thereby increasing single fruit weight (5550 g) and thus increased yield. In seeds extracted from previous rainy season crop, increase in number of fruits resulted in higher yield. From the above results it can be stated that, use of growth regulators results in higher fruit weight thereby resulting in higher yield while the seeds from previous season increases the number of fruits and hence an increased yield. Kumar and Singh (1998) reported that in bottle gourd yield per plant was positively correlated with number of fruits per plant. Thus seeds treated with GA_3 50 ppm was found to increase the fruit yield of seed crop.

Though not significant, highest per cent fruit set was obtained from seeds treated with GA_3 100 ppm (64.44), which was closely followed by seeds extracted from intact stored fruits of previous rainy season crop (62.10). The treatment with high concentration of growth regulator might have helped in the synthesis of more florigen and carbohydrates, there by inducing production of more flowers. However, since the production of growth hormones within the pollen is the

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immediate cause of fruit-set, it appears that the seed treatment with adequate quantities of growth hormones might have induced formation of sufficient hormones within pollen, thus resulting in increased fruit-set (Sadawarte and Gupta, 1968). This may be the reason for increased per cent fruit set in plants raised from seeds treated with GA_3 100 ppm. But GA_3 100 ppm did not give a significantly higher yield in the present study. This is in accordance with the result of Vanangamudi *et al.*, (1988) who found that seeds of onion soaked with GA_3 200 ppm did not influence bulb yield and seed yield where as it significantly improved flowering from 2.1 to 6.9 per cent.

Node at which the first female flower appeared was non significant. However seeds extracted from intact fruits of previous rainy season crop flowered at later nodes (14.43) and seeds extracted from intact fruits of previous summer season crop flowered at earlier nodes (12.75). Seed invigoration with NAA 50 ppm increased vegetable yield, where as GA_3 50 ppm gave maximum fruit and seed yield, when grown for seed purpose. Foliar application of growth regulators along with seed treatment might have improved the yield further. Patil and Ballal, (1980) reported a reduced flower drop and an increased yield in chilli due to combination of foliar sprays and seed treatment. The effect of such type of combination sprays are to be studied in detail.

In general the number of seeds per fruit was less in all the treatments. Maximum number of seeds per fruit (217.33) was recorded by GA_3 50 ppm treated seeds, which was followed by fruits produced from extracted and stored seeds from previous rainy season crop (210.17). Hundred seed weight was maximum (6.35) for fruits produced from plants raised from extracted seeds of previous rainy season and seeds treated with NAA 25 ppm. Earlier reports show that the foliar application of 10 ppm NAA increased seed yield and 100 seed weight in *Vicia faba* (Huang *et al.*, 1989). Seeds extracted from previous summer season crop had the minimum number of seeds (80.50) and least hundred seed weight. Seeds extracted and stored over a longer period of time should not be used

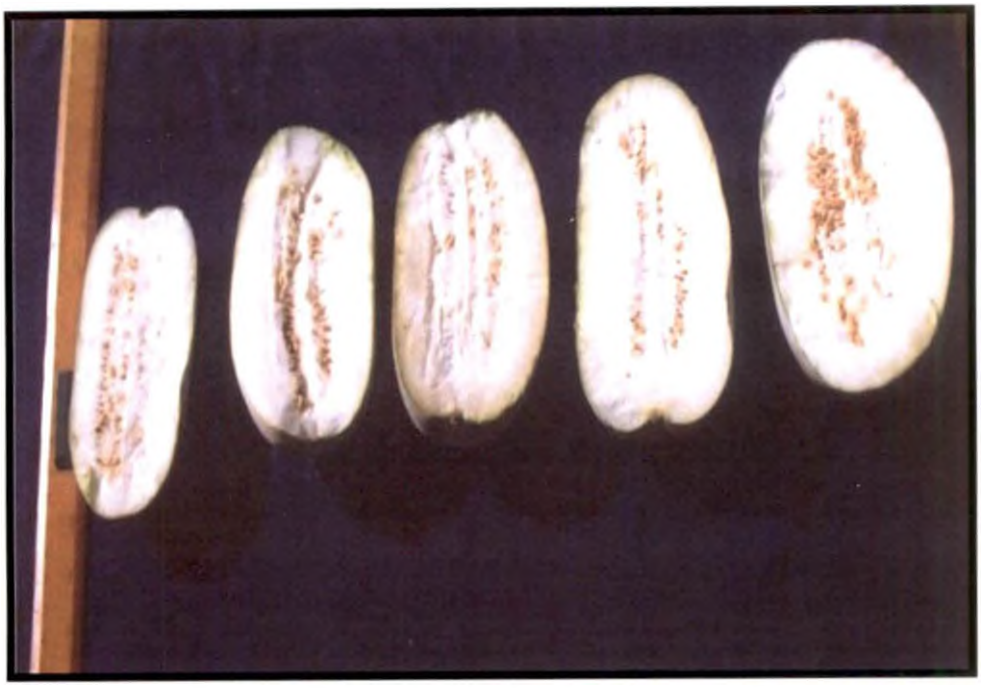

Plate 4. Cross section of fruits exhibiting less number of seeds

for seed production programme. Seed yield per plot was very high (225.69) in fruits of plants raised from extracted and stored seeds of previous rainy season crop. All other treatments behaved similarly. This clearly indicates the superiority of using seeds which are extracted and stored for three months which is again due to influence of after ripening.

Seeds treated with 1 % KNO_3 resulted in poor field emergence (40.83), increased number of primary branches (2.10), delayed flowering (57.33 days), least number of fruits per plant for vegetable (1.72) and seed purpose (1.55), minimum circumference of fruit for vegetable (37.67) and seed purpose (56.05), reduced number of seeds per fruit (126.67) and low hundered seed weight (5.54). The single fruit weight for vegetable (1991.00) and seed purpose (3520.00) was minimum and thus yield per plot was also poor. Therefore KNO_3, though found to be effective in several references of seed invigoration, failed to give better field performance in the present study. KNO_3, which was comparatively ineffective in invigoration of ashgourd in the present study, could not perform better in the field also. This clearly indicates a correlation between laboratory and field performance.

Plants raised using seeds of previous rainy season crop exhibited superiority in several aspects. Seeds extracted from intact stored fruit of previous rainy season crop at the time of sowing had maximum field emergence, vine length, higher percentage of fruit set and single fruit weight, more fruits with more number of seeds in it and highest fruit yield. Similarly seeds extracted and stored from previous rainy season had maximum field emergence, flower production on earlier nodes, high single fruit weight, produced maximum number of fruits per plants (at seed harvest) and seeds per fruit, had highest hundred seed weight, fruit and seed yield.

Inferiority of seeds extracted from previous summer season crop was expressed as low field emergence, minimum per cent fruit set, delayed flowering,

minimum single fruit weight, less number of fruits per plant and low yield. The seed quality parameters like hundred seed weight and number of seeds per fruit were also least. Therefore use of already extracted seeds from previous summer season crop is not advisable for vegetable or seed production.

5.4 EVALUATION OF THE SEEDS EXTRACTED FROM THE FIELD STUDY

Seeds collected from the field crop were subjected for evaluation under laboratory condition. Seeds treated with GA_3 25 ppm recorded superior germination per cent (66.09), speed of germination (10.22) and vigour index I (1189). This was closely followed by seeds treated with NAA 25 ppm which recorded a superior vegetable yield and hundered seed weight in the field evaluation study. Seed invigoration with GA_3 50 ppm, though resulted in increased fruit yield (Table 29) at seed harvest, it could not produce seeds of good quality. Those seeds had a germination per cent of 38.00,speed of germination of 6.23 and vigour index I of 717. This might be further enhanced by giving an after ripening, thereby releasing the dormancy completely. Though not effective in producing quality seeds, plants raised from invigorated seeds, did not produce any abnormal seedlings i.e. seed invigoration do not result in further seed abnormality. Seeds extracted from fruits of previous summer season crop had minimum germination per cent (6.00) speed of germination (0.69) and vigour index I (65.00). The poor performance of the crop raised from previous summer season crop results in production of poor quality seeds also. Hence these seeds cannot be recommended for further cultivation. But seeds collected from crop of previous rainy season crop was superior, resulting in higher seed quality parameters.

The effect of prolonged storage of invigorated seeds is to be studied in detail. The effect of using growth regulators as seed treatment in combination with plant sprays may further increase the vegetable and seed yield. Such detailed

studies are to be conducted. Since the crop was raised for one season only recommendations could not be made. So the superior treatments are to be repeated for confirmatory results.

Summary

6. SUMMARY

The present study was conducted to find out the effect of invigoration to break seed dormancy in ash gourd, to find out the storage potential of invigorated seeds and, to compare the field performance of invigorated seeds with certain traditional farmers practices.

Different invigoration treatments were tried in freshly harvested ash gourd seeds for a period of six months. None of the treatments could give a steady performance in breaking dormancy throughout the period of study. Even then seed invigoration was found to be beneficial when compared with the untreated seeds. Untreated seeds did not attain the required minimum germination even after five months of storage. These seeds gave a germination of 28 per cent immediately after extraction, which was increased only to 56.33 per cent at 5 MAE.

Analysis of overall performance revealed that performance of the GA_3 was found to be effective at all concentrations (25.50 and 100 ppm) but NAA at higher concentration was not very promising. Seeds treated with GA_3 50 ppm resulted in maximum germination per cent and vigour index I. GA_3 100 ppm treated seeds resulted in maximum speed of germination (13.94). Seeds invigorated with NAA 25 ppm gave maximum vigour index I (964) and II (4.18).

Seed treatment with water, either cold or hot, was found to be ineffective in the present investigation. Though acid treatments were found to be superior during some months, the overall performance revealed that they were inferior. Scarification did not have a major role in breaking dormancy in ash gourd, where as growth regulators were effective in breaking dormancy and improving germination. The present study revealed that the failure of fresh ash gourd seeds to germinate may be attributed to certain chemical blocks and not due to physical

blocks. Dormancy in ash gourd might be endogenous in nature, which is controlled by hormones. Dormancy can be broken by an after ripening period of two months and if the after ripened seeds are invigorated, vigour can be further improved.

Based on the overall performance, treatments GA_3 25, 50, 100 ppm, NAA 25, 50 ppm and KNO_3 1% were selected for further study. The fresh seeds were given an after ripening period of two months and subjected to a storage study using the six treatments selected.

The germination per cent of invigorated seeds showed a gradual reduction during storage exhibiting a germination of 87.81 per cent at one month after storage (MAS) to 59.26 at 6 MAS. Though it showed a gradual reduction, the germination could be maintained above the minimum requirement (60.00) even at 5MAS except in seeds invigorated with GA_3 25 ppm. Hence seeds treated with GA_3 25 ppm cannot be stored. There was a gradual reduction in the speed of germination and vigour index I during the period of storage. No correlation could be obtained between electrical conductivity and seed quality. So it cannot be taken as a suitable test for seed quality in ash gourd. However the invigorated seeds can be safely stored for a period of 5 months and can be directly supplied to the farmers for immediate use.

The field performance of invigorated seeds was compared with seeds collected from previous summer and rainy season crop in two different methods. In one of the treatments seeds were extracted and stored till next sowing and in other intact fruits were stored and seeds extracted at the time of sowing.

Seeds of previous rainy season crop were found to have maximum field emergence. The seeds extracted from previous summer season crop had least field emergence. Plants raised from extracted and stored seeds of previous rainy season

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crop produced maximum number of fruits per plant (3.42), when harvested for vegetable purpose.

The practice of storing intact fruits and collecting seeds at the time of sowing from previous rainy season crop is found to be superior, producing higher vegetable yield. Fruit yield per plant for vegetable purpose was maximum (4.33) for seeds treated with NAA 50 ppm and seeds extracted from intact fruits of previous rainy season crop (4.31). Among growth regulators, NAA 50 ppm could be recommended for increased vegetable yield as it produced more number of fruits (2.78), number of primary branches (2.42) and maximum fruit length (32.75), there by increasing the yield.

Seeds extracted and stored from previous rainy season and those treated with GA_3 50 ppm gave maximum yield (10.22 and 9.60 kg) for seed purpose. Seeds treated with GA_3 50 ppm exhibited highest fruit circumference and fruit length resulting in higher fruit weight and increased yield. Use of growth regulators increased the size of the fruit and thereby an increased fruit yield when grown for seed purpose. On the other hand seeds extracted from previous season crop had more number of fruits per plant (4.33), thereby increasing the fruit yield.

More number (210.17) of seeds per fruit ,maximum hundred seed weight (6.35) and seed yield (225.69) were recorded in fruits of plants raised from extracted and stored seeds of previous rainy season crop. It is evident that the seeds can be extracted from previous rainy season crop and stored till next sowing in summer for better seed yield. Seed treatment with KNO_3 is not advisable in ash gourd as it gave poor field performance.

The number of seeds per fruit and hundred seed weight were least for seeds extracted from previous summer season crop, and it resulted in poor quality parameters like germination per cent, speed of germination and vigour index I.

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* Originals not seen

Appendices

APPENDIX-I

Weather data during the period of study (January 2003 to May 2004)

Period	Temperature		Relative humidity %	Rainfall (cm)
	Max^{0}C	Min^{0}C		
01-01-03 to 31-01-03	33.2	22.9	50	9.4
01-02-03 to 28-02-03	34.7	23.6	63	9.2
01-03-03 to 31-03-03	34.6	24.1	67	8.5
01-04-03 to 30-04-03	34.6	25.0	72	7.5
01-05-03 to 31-05-03	34.0	25.0	72	6.3
01-06-03 to 30-06-03	30.9	23.0	80	4.0
01-07-03 to 31-07-03	29.5	22.2	84	2.5
01-08-03 to 31-08-03	30.0	23.4	83	4.2
01-09-04 to 30-09-04	31.0	22.7	79	7.3
01-10-03 to 31-10-03	30.8	23.1	81	5.6
01-11-03 to 30-11-03	31.5	23.9	66	7.1
01-12-03 to 31-12-03	32.2	21.9	61	9.1
01-01-04 to 31-01-04	33.4	22.3	58	9.6
01-02-04 to 29-02-04	35.2	22.5	50	9.6
01-03-04 to 31-03-04	36.5	24.2	61	8.6
01-04-04 to 30-04-04	34.8	25.2	69	7.4
01-05-04 to 31-05-04	30.4	23.6	84	3.4

SEED INVIGORATION STUDIES IN ASH GOURD (*Benincasa hispida* Thunb.)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

"Seed invigoration studies in ash gourd (*Benincasa hispida* Thunb.)"was carried out at Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2002-2004. The study was conducted to find out the effect of invigoration to break seed dormancy in ash gourd, to find out the storage potential of invigorated seeds and to compare the field performance of invigorated seeds with certain traditional farmers' practices.

Among the different invigoration treatments tried, growth regulators were found to be effective in breaking dormancy of fresh ash gourd seed and to improve vigour. GA_3 was effective at 25, 50 and 100 ppm and NAA at 25 and 50 ppm. Acid treatment or water soaking did not have any effect in breaking dormancy, thus indicating the inefficiency of scarification. Seed dormancy in ash gourd is found to be endogenous in nature which is due to certain chemical blocks, caused either by the presence of growth inhibiting factors or due to deficiency of some essential compounds.

Seed invigoration was not effective in breaking dormancy of fresh seeds. But fresh seeds can be given an after ripening for a period of two months and invigorated with growth regulators for increased vigour.

Though there was a gradual reduction in quality parameters like germination percentage, speed of germination and vigour index. Invigorated seeds can be safely stored for a period upto five months indicating that invigorated seeds can be directly supplied to farmers for immediate use.

The practice of using seeds from previous rainy season crop was found to give superior field performance during next summer. Storing the harvested fruits as such and extracting seeds at the time of sowing gives better vegetable yield, where as storing the extracted seeds till next summer gave better fruit yield for

seed purpose and seed yield. Among the growth regulators seeds invigorated with NAA 50 ppm gave increased vegetable yield and GA_3 50 ppm gave increased seed yield.

KNO_3 was not effective in breaking dormancy, improving vigour or giving improved field performance in ash gourd. Using seeds of previous summer crop for next summer is found to give inferior field performance and seed quality.