PROPAGATION TECHNIQUES OF *Moringa oleifera* Lam.

THESIS

By

GOPAL KRISHAN SHARMA

HIMACHAL PRADESH KRISHI VISHVA VIDYALAYA

COLLEGE OF AGRICULTURE

SOLAN

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GOPAL KRISHAN SHARMA

A Thesis submitted

to

Himachal Pradesh Krishi Vishva Vidyalaya

College of Agriculture, Solan

in partial fulfilment of the requirements

for the degree of

M A S T E R O F S C I E N C E

in

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Prof. V. Raina,
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Solan (H.P.)

CERTIFICATE

This is to certify that the thesis entitled "Propagation techniques of *Moringa oleifera* Lam." submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in Forestry of Himachal Pradesh Krishi Vishva Vidyalaya, is a faithful record of the research work carried out by Sh.Gopal Krishan Sharma, under my guidance and supervision.

No part of the thesis has been submitted for any other degree or diploma. All the assistance received during the course of these investigations and the source of literature have been fully acknowledged by him.

(V. Raina)

Solan

Date: 2nd June, 1980.

CERTIFICATE

This is to certify that thesis entitled "Propagation techniques of *Moringa oleifera* Lam." submitted by Sh.Gopal Krishan Sharma to the Himachal Pradesh Krishi Vishva Vidyalaya, in partial fulfilment of the degree of MASTER OF SCIENCE in Forestry has been approved by the Student Advisory Committee after an oral examination of the same in collaboration with an External Examiner.

EXTERNAL EXAMINER

ADVISORY COMMITTEE

Chairman _____ (Prof.V.Rajan) 8/9/80

Members 1. _____ (Dr.P.K.Ishwala)

2. _____ (Dr.P.C.Katoch) 12/9/80

3. _____ (Dr.A.N.Kaushal)

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Dr. P. L. Chauhan.

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Before beginning to detail my research project and the studies conducted, I have a very important and of course a very pleasant duty to perform. "Duty" perhaps, is not the right word, for it is infact a mythical logic, that compels me to let my examiners know, as to who have worked with me, behind the scene, and enabled me to present this document as a thesis.

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(G. K. Sharma)

CONTENTS

INTRODUCTION

Fodder trees assume special importance in the lower hills of Himachal Pradesh where at times leafy twigs are the only source of green fodder for the cattle. Moringa oleifera Lam. Syn. Moringa pterygosperma Gaertn. belongs to the family Moringaceae and is commonly known as drumstick. In Himachal Pradesh the tree is called sahunjna or sohanjna. It is an indigenous tree growing widely in the north sub-Himalayan tract and from Chenab eastwards to Sarda in the south (Troup, 1921). It is plentiful on recent alluvial land particularly in North-West India near sandy beds of rivers and streams. In Himachal Pradesh its occurrence is limited and grows sporadically in the sub-Himalayan tract, viz. in the parts of civil districts of Bilaspur, Kangra, Hamirpur, Una, Mandi, Sirmur and Solan. Three varieties are reported to occur in India, viz. Jaffna, Chavakacheri murunga and Ghana murunga. These varieties are not recognised botanically.

Various parts of M. oleifera are used for different purposes. Tender twigs and leaves are lopped for fodder (Burkill and Parker, 1947). The leaves are rich in carotene (vitamin A) and ascorbic acid (vitamin C) as well as in protein content (Bagchi and Sreenivasan, 1945). The tender pods and seeds are eaten as vegetables.

Flower and tender leaves are eaten as pot herb. The roots of the tree are used as condiment or garnish. The stem of the tree exudes a gum which is locally used in calico printing. The corky grey bark yields a coarse fibre which might be utilized in preparing mats, paper or cordage (Chopra, 1933).

Besides, the tree has been known and appreciated in India for its medicinal value. Many of its parts such as roots, bark, gum, leaves, flowers, seed and the seed oil, have been used for various ailments in indigenous medicines. Two important alkaloids, Moringine and Moringinine extracted from root bark, are used in the allopathic medicines.

In its natural habitat Sohanjna grows in all types of soils except stiff clays and thrives best under tropical insular climate of South India.

However, the major constraint in attempting for extensive propagation of the tree is its lack of information. In view of the multiple uses and high nutritive fodder value, the suitable methods are required to be investigated for the multiplication of this tree in the sub-Himalayan tract of Himachal Pradesh.

The present investigation was therefore conducted to collect and collate information under following mentioned objectives:-

1. To standardise the seed germination method in order to find out:

   (a) Effect of storage containers and storage period on seed germination.

   (b) The germination behaviour and presence of physical as well as physiological dormancy of seeds by soaking in water.

   (c) Effect of dilute acid solution (HCl) on germination behaviour.

   (d) Effect of depth of sowing on seed germination.

2. To standardise the vegetative propagation in order to find out:

   (a) The response of the species to the propagation by 1 and 2 year old branch cuttings and through air-layering.

   (b) The possibility of use of plant regulators in its propagation by these methods.

Moringa oleifera Lam. of family Moringaceae is a small or middle sized tree; bark corky; wood soft; root pungent; young part tomentose. Leaves usually 3-pinnate, sometimes 45 cm long; rhachis slender, thickened and articulated at the base; pinnae and pinnules opposite, deciduous, their rhachides very slender, articulated and with a gland at the articulations; ultimate leaflets 12-20 by 6-10 mm, the lateral elliptic, the terminal obovate; the lateral leaflets 1.5-2.5 mm, those of the terminal 3-6 mm long. Flowers white, in large puberulous panicles. Calyx- lobes linear-lanceolate reflexed, puberulous outside. Petals spathulate, veined. Stamens 5 fertile, alternating with 5-7 antherless ones; filaments villous at the base. Ovary oblong, villous; style cylindric. Pods reaching 45 cm long, 9-ribbed. Seeds 3- angled, the angles winged (Kirtikar and Basu, 1975).

The propagation in the South Indian conditions as reported by various workers is either through seeds or by cuttings. Under south Indian conditions it survives best and is evergreen. Troup(1921) reported that its evergreen nature is due to the temperature and rainfall which varies from 41°C to 48°C and 750 mm to 2150 mm, respectively. In the present investigation attempts were made to propagate Moringa oleifera by seeds, cuttings and air layering. Within these broad groups review of work done is summarized below-

1. BY SEEDS:

Seed is most common means of propagation for self and cross pollinated plants. Most seeds present no problem in germination and germinate when sown at appropriate season and stage of the seed. Troup(1921) reported that Moringa oleifera can be grown by seeds and cuttings. Seth et al., (1962) reported that average germination per cent is 66 and germination commences on about the 9th day after sowing.

The seeds of many species fail to germinate inspite of the presence of favourable environmental conditions. Janick (1974) termed this state as seed dormancy. Seed dormancy has been attributed to one or more of the following reasons (Wareing and Phillips, 1970; Barton, 1965; Lang, 1965; Stokes, 1965).

(i) Hard and impermeable seed coat.

(ii) Immaturity of embryo.

(iii) After ripening in dry storage.

(iv) Light sensitivity of seeds.

Various workers have reviewed the above factors from time to time (Brant et al., 1971; Nikolaeva, 1969; Barton, 1965, 1967; Flint and Mc Alister, 1937; Scott and Draper, 1967; Hartmann and Kester, 1967; Rolston, 1978; Copeland, 1976; Crocker and Barton, 1963; Salisbury and Ross, 1969; Villiers, 1972). Donnelly (1970) reported that besides environmental factors the genetic component

Flowering branches of Moringa oleifera.

Fruiting branches of Moringa oleifera.

of the plant also causes dormancy.

Seed storage:

Seeds are usually stored for varying lengths of time after harvest. Viability at the end of any storage period is the result of (a) the initial viability at harvest, as determined by factors of production and methods of handling, and (b) the rate at which deterioration takes place. This rate of physiological change or aging is associated with (i) the kind of species of seed, and (ii) the environmental conditions of storage, primarily temperature and relative humidity (Hartmann and Kester, 1972).

Literature has been reviewed by a large number of workers who contributed on the storage of seeds, namely, Bonner (1978), Barton, (1961) Roberts (1972), Holmes and Buszewicz (1958), Stein et al., (1974), Wang (1974). The handling of seeds after maturity required great care. The present review is dealt under different headings.

Prestorage care:

Most seeds of trees fall into one of the three categories of seed storage:-

(i) Seeds that are dried before storage.

(ii) Seeds that must be kept moist for storage.

(iii) Seeds that must be kept moist for extraction and then dried for storage.

Most of the hardwood small seeded trees fall in the first group such as Casuarina, Eucalyptus, Moringa, and Platanus (Bonner, 1978).

The second category contains the seeds which are difficult to store after drying and they loose their viability on drying such as Aesculus, Dipterocarpus, Hopea, and Quercus (Tang and Tamari, 1973).

The third category includes mainly drupes and other fleshy fruits such as Gmelina, Malus, Melia, Prunus and Ziziphus.

Storage Conditions:

The two objectives of storage are to maintain seed stock as cheaply as possible until they are needed and to preserve seed quality as far as possible. Seeds stored for longer duration generally loose their quality but if proper steps of storage are undertaken the quality can be maintained.

Tree seeds are divided into two groups for storage procedures:-

(i) Species that can be kept at low moisture -

(ii) Species that can be kept at high moisture.

Seeds of the first group are easy to store for longer duration and generally the seed moisture content is

maintained between 5 and 10 per cent (Bonner, 1976). Examples of this group include Acer saccharum (Young and Carl, 1974); Betula alleghaniensis (Clausen, 1975); Carya ovata (Bonner, 1976); Eucalyptus spp. (Krugman, 1974); Fraxinus americana (Schreiner, 1974) and Ulmus rubra (Hall, 1967).

The other group of seeds that require high moisture content for storage are maintained at 35-40 per cent of the moisture and most of the Quercus spp. are included in this group (Bonner, 1973; Suszka, 1974).

Storage containers

Dubral (1976) reported that the freshly extracted seeds of teak (Tectona grandis) can be stored in air tight containers under the cover of fungicide dust. Seeds stored upto 2 months have so far been tried and gave germination upto 54 per cent. The too wet conditions cause decay of seeds.

According to Hartmann and Kester (1976) the purpose of soaking seeds in water is to soften hard seed coats, remove inhibitors, soften seeds and reduce the time of germination. This treatment will overcome seed coat dormancy and stimulate germination in some cases.

Pre-soaking

Soaking the seeds in water before sowing enhances germination in most of the species. This procedure has been

used for germinating Celery (Taylor, 1949). Cold soaking the seeds of some conifers, such as, coultes pine, montary pine and douglas fir for 24 hours just above freezing sometimes proves beneficial. Soaking of Robinia pseudoacacia seeds was not found to be useful by Troup(1921). Debral (1976) reported that soaking of teak seeds in water before sowing was harmful.

Acid treatment:

The purpose of acid scarification is to modify hard and impermeable seed covering. According to Hartmann and Kester (1976), dry seeds should be placed in glass or earthegn ware containers and covered with concentrated sulphuric acid (specific gravity 1.84) in a ratio of about one part seed to two parts acid. The time of treatment may vary from species to species.

Singh and Soni (1974) reported that soaking the seeds of Guava cultivars, Allahabad Safeda and Red fleshed cultivars for 3 minutes in hydrochloric acid improved the germination over 90 per cent compared with 58 per cent from untreated control. Pathak (1976) reported that nine minutes scarification with concentrated sulphuric acid gives maximum germination in Robinia pseudoacacia seeds.

Depth of sowing

Few studies have been conducted to unravel the effect of sowing of seeds at various depths of soil.

Singh et al., (1973) reported higher percentage of germination in Kail (*Pinus wallichiana*) seeds at 15 mm soil depth.

2. BY CUTTINGS:

Rooting of cuttings is the simplest and least expensive method of vegetative propagation of many species. In this a portion of stem, root or leaf is cut from parent plant, which is placed under certain favourable environmental conditions and indjced to form roots and shoots, thus producing a new independent plant (Hartmann and Kester, 1976).

Although this method of propagation has been practised since times immemorial, the first scientific paper on rooting of cuttings was published by Duhamel du Monceau in the year 1758. A considerable amount of literature dealing with different aspects of rooting have accumulated since then and reveal that the rooting potential of plant species varies considerably (Vanderick, 1925; Jiminez, 1937; Stoutemyer, 1937; Fadl and Hartmann, 1968).

Cuttings of some plants root easily, others root with difficulty and still others do not root at all. It is an obscure and still unanswered question why some cuttings do not root easily and others hardly ever.

Season has a paramount role to play in rooting of stem cuttings. Some cuttings root throughout the year, while others are seasonal. The magnitude of rooting even in species that root throughout the year varies considerably with season (Hitchcock and Zimmerman, 1930; Brandon, 1939). Sood (1978) reported that season played a main role in the root and shoot formation in Grewia optiva, Morus alba and Cordia dichotoma. Grigorov and Halacsy (1956) reported that highest percentage of rooting and of first grade plant in case of fig came from cuttings taken at the beginning of November and April. They concluded that the most active period of root formation on the cuttings was May and June.

Temperature also influences the formation of callus and also the initiation and development of roots on stem cuttings. Hamode (1958) obtained better rooting of stem cuttings when the beds were maintained at a relatively higher temperature. Gardner (1929) reported that the rooting potential of stem cuttings decreases with the age of the mother plant.

Zimmerman and Wilcoxon (1935) and Thimann (1935) reported that Indolebutyric acid (IBA), although not naturally occurring, was more effective than naturally occurring IAA in inducing the rooting in stem cuttings. The extensive literature on the effect of auxins in rooting has been adequately reviewed from time to time

(Went and Thimann, 1937; Swingle, 1940; Leopold, 1960).

Auxins, in general, promote rooting at low but inhibit it at high concentrations. There are many plant species which do not root even with application of auxins (Pearse, 1939).

Nanda (1969) reported that auxins enhanced rooting, IBA being most effective even when applied to the cuttings apically prior to inverted planting. Stem cuttings of most of the tried members of some families rooted easily, while those of others were obstinate, indicating a closer relationship of the members of the same family with respect to internal factors determining rooting potential. Seasonal rooting response of stem cuttings of these species was also related with the disappearance of starch, the low rooting corresponding with high and profuse rooting with low starch content.

In propagation by stem cuttings it is necessary that a new root and shoot system be formed. A new shoot system is formed from an adventitious bud and a new root system from a group of meristematic cells. Many cells, even in mature plant parts, have the capability of returning to the meristematic condition and forming root or shoot systems.

Bud initiation on cuttings is stimulated by application of growth hormones. Auxin isolated from urine was first demonstrated to have root forming property (Thimann

and Went, 1934). Since then numerous tests and practical applications in the use of synthetic chemicals in several plant materials have been reported. Indole-3-acetic acid (IAA) is known to be the most widely occurring auxin, but its suitability as a rooting hormone for practical application is far less satisfactory. It is highly mobile and easily inactivated, thus it becomes less stable and persistent. While IBA do not show these undesirable effects.

Lee (1976) reported in Taxodium distichum that rooting of cutting was obtained best in the month of April. Alley and Peterson (1977) reported in grapevine that cuttings are greatly affected by temperature, refrigeration, IBA concentration on callusing and rooting of dormant cutting. IBA hastens the appearance of calles and root formation but not bud burst. Ghosh and Bhatnagar (1977) observed in Populus gamblei that 200 ppm of IAA or IBA was best for rooting taken in the month of November. Mahlaui et al., (1976) reported the rooting of olive soft wood cuttings with the application of IBA (5000 ppm, 6 second dip). Goi et al., (1978 a) observed that Nepthalic acetic acid (NAA) (0-50 ppm) was effective in forming roots in soft wood cuttings of Ilex rotunda. Goi et al., (1978 b) reported that when hard wood cuttings were taken and treated with NAA/IBA (0-50 ppm) in Chaenomeles, were ineffective in response to the rooting formation. Sinha et al., (1962) observed poor rooting

in guava cuttings treated with plant growth regulators.

Woody plants in general require a higher concentration of hormones than the herbaceous plants. Rooting was induced in the cuttings of Poinsettia pulcherrima by treating with IBA at 5-10 ppm while the same treatments failed to induce rooting from the cuttings of Mangifera indica and Syzygium cumini. Chandra (1956) reported that Rauvolfia tetraphylla can be raised by vegetative means with hard wood cuttings after treatment with IAA.

Bhattacharya and Bhaduri (1959) obtained better rooting after treating soft wood cuttings of Rauvolfia serpentina with 1000 and 5000 ppm of IBA. Singh (1956) reported vegetative propagation of Kigelia pinnata by inducing rooting on hardwood cuttings with 20 ppm IBA for 12 hour treatment. In Justicia, IAA and IBA in combination with sucrose gave significant increase in the number of roots. Among IAA, IBA and NAA, the last proved effective, whereas other two have no effect in the induction of rooting of the twigs of Magnolia grandiflora (Samantarai, 1955).

Hard wood cuttings like Thuja, Juniperus species root well and Taxus species fairly well while Picea, Tsuga, Abies and Pinus spp. are difficult to root (Nelson, 1959; Swarteley and Chadwick, 1939; Myhre and Schwartze, 1948).

3. BY AIR-LAYERING:

Adriance and Brison (1967) have defined layering to be a propagation method by which adventitious roots are caused to form on the stem while it is still attached to parent plant. The rooted or layered stem is then detached to become a new plant growing on its own roots.

Hartmann and Kester (1976) stated that the root formation during layering is stimulated by various stem treatments, which cause an interruption in the downward translocation of organic materials-carbohydrates, auxins and other growth factors from leaves and growing shoot tops. These materials accumulate near the point of treatment and rooting occurs in this general area even though the stem is still attached to the parent plant.

According to Naik (1967) the air layering involves the rooting of plants while they are still attached to parent plant. It is accomplished by wounding or girdling of a branch and covering the wounded part with soil or organic matter. After rooting the terminal part is removed from the plant and out planted. Air layers of woody plants initiate callus development followed by root formation at the physiological base of the incision. These steps can be enhanced by the application of auxins, generally weak auxins.

Wrapping with sphagnum moss alone may be adequate if humidity is very high or daily syringing is practised (Naik, 1967). Du Preez (1954) and Grove (1947) reported

that polythene film which has high permeability to gases, low transmission of water vapour and sufficient durability to withstand long periods of weathering, has largely replaced other materials for covering the rooting media.

Field and Garner (1940), Nat Kins (1952) and Mowry et al., (1953) reported that air layering is used successfully to propagate a large number of sub-tropical and tropical trees and shrubs. Rao (1953) reported that Moringa oleifera can possibly be propagated by air layering.

Application of root promoting substances such as IBA, NAA, IAA etc. during air layering is sometimes beneficial. Jayant Kumar (1979) reported 70.4 per cent success in Murraya koenigii with 5000 ppm IBA. Other formulations like Seradix-B and Rootone have also shown encouraging results. Chhokar and Singh (1972) found that IBA 5000 ppm was more effective than NAA in promoting the rooting and establishment of mango marcots. The application at the time of ringing was less effective than application one day later. Alkathene was better wrapping material than gunny cloth.

Green (1962) found that air layering on lateral branches gives better rooting than on terminal shoots. Madhava Rao (1958) observed that one year old shoots in cashewnut appeared to have tendency to produce larger number of roots than the current season shoots.

Mohamad Husain (1966) reported that rooting response was favoured by temperature and application of nutrient solution in Eucalyptus.

Season has a paramount role to play in callus formation of forest trees. The marked seasonal variability of rooting of Salix atrocinerea was emphasized by Vieitez and Pena (1968). Air layering with IBA, NAA and Seradix at concentrations of 1,000 to 10,000 ppm gave 100 per cent rooting in Anharatia nobilis and 60 to 80 per cent in Mesua ferrea.

The active phase of root regeneration occurred during January to April and a lesser phase lasted from May to August and a few roots initiated from September to December (Doran, 1957). Khosla et al., (1980) conducted air layering experiments on Morus alba, Ficus carica, Grewia optiva and reported that application of IBA (0 to 1,000 ppm) enhanced differentiation of callused layer to rooted layer in shorter duration in all the seasons i.e. pre-monsoon, monsoon and post-monsoon. Bloomberg (1964) observed that temperature influences the callus formation. Khosla et al., (1979) also supported it.

Jauhari and Nigam (1958) and Jauhari (1960) reported in Carissa carandas that concentration higher than 10,000 ppm of IBA and NAA limited rooting response to 20 to 40 per cent, while the lower concentrations caused 100 per cent rooting in 2 year twigs.

Vorob'ev (1978) reported in 4 year old shoots of Hippophae rhamnoides IBA (17 mg/g) or IAA (20 mg/g) caused air layers to root within 25 days, when leaves and current year shoots were removed.

MATERIAL AND METHODS

The present investigations on the standardization of propagation techniques for *Moringa oleifera* Lam. of sub-Himalayan zone in Himachal Pradesh were carried out in the Department of Forestry, Himachal Pradesh Krishi Vishva Vidyalaya, Solan since July, 1978. Experimental trials were laid out in the nursery areas of Shilli (Solan), New Campus Gachghat (Solan), Nihari(Bilaspur) and Sanan (Arki). Details of methods followed and techniques adopted during the course of these investigations, are outlined below

A. PROPAGATION BY SEEDS:

1. Collection:

The seeds were collected from fully matured fresh fruits obtained from the mature mother plants in the month of May and June. The seeds were extracted from the pods and dried in shade before giving pre-sowing treatment or direct sowing.

2. Storage:

After proper drying, one kilogram of seed (about 990 in numbers) was stored in each of the following four types of containers.

(i) Open tray (T_1)

(ii) Air tight tin (T_2)

(iii) Gunny bag (T_3)

(iv) Plastic jar (T_4)

The seeds were stored in these containers for a period of one month after which 300 seeds (3 replicates

of 100 seeds each) were sown from each lot to determine the effect of storage containers on seed germination.

Seeds for sowing experiments were stored seperately in a plastic jar at room temperature. To determine the effect of storage period on germination sowing was done from this jar in three lots after a storage period of one month (T_1), two months (T_2) and three months (T_3).

3. Sowing:

3.1 Normal sowing:

With a view to determine initial germination response, 150 seeds in three replicates of 50 each were sown in the nursery beds in the month of July. The seeds were sown at a depth of 10 cm and the spacing between seeds was 10 cm and between rows 20 cm. Also to determine germination behaviour under laboratory conditions 90 seeds in 3 replicates of 30 each were kept in Petri dishes in a BOD incubator at 25°C.

3.2 Sowing after pre-treatments:

Following two treatments were given to seeds before sowing.

3.2(1) Acid treatment:

The seeds were pre-treated with hydrochloric acid at a concentrations of 0.1(T_4), 0.2(T_5), 0.5(T_6) and 1 (T_7) per cent for twenty seconds. After that seeds were washed thoroughly with tap water in order to make them

free from acid and then excess of moisture was removed by holding them in between two sheets of filter paper. The dried seeds were sown in the nursery beds exactly in the same manner as stated in 3.1.

3.2(ii) Pre-soaking in water:

The seeds were soaked in distilled water for 0(T_1), 12(T_2) and 24 (T_3) hours. The wet seeds were dried within the folds of filter paper and sown in beds at a spacing of 10 cm x 20 cm. In each treatment 555 seeds were sown in three replicates of 185 seeds each.

3.3. Sowing at different depth:

The seeds were sown in the beds at the following depths:-

(i) 5 mm (T_1)

(ii) 10 mm (T_2)

(iii) 15 mm (T_3)

(iv) 20 mm (T_4)

The spacing was kept same as in 3.2.(ii). In each treatment 165 seeds were sown in three replicates of 55 each.

With a view to protect the seeds from fungal attack and soil born diseases, they were treated with 0.2 per cent solutions of Captan (for 10 seconds) just before sowing. For minimising the insect attack the soil was thoroughly mixed with BHC (15%) at the time of nursery bed preparation.

4. Recording of observations

Observations were recorded in regard to emergence of seedlings, height and diameter of the seedlings.

The nursery area was visited every day in the morning and emergence of seedlings was recorded, if any. This observation was made till the last seedling emerged from the nursery bed.

The height of the seedlings was measured at a period of 3 months after sowing of seeds in the nursery. The measurement was done with the help of a meter scale.

The diameter of the seedlings was recorded along with the height. It was recorded with the help of a Vernier calliper at ground level.

B. PROPAGATION BY CUTTINGS:

1. Preparation of cuttings:

Hard wood cuttings, 20.00 cm in length and 0.75 to 2.0 cm in mid diameter, were prepared from one and two year old healthy tree branches from Bilaspur, Sanan (Arki) and Ghumar (Arki) areas.

2. Treatments:

2.1. Indole butyric acid (IBA):

The cuttings were treated with IBA solution of different concentrations (0, 50, 100, 150, 200 and 500 ppm) by long time dip method. IBA solution was prepared by

dissolving the requisite quantity of the chemical first in a small quantity of ethyl alcohol and then making the desired volume with distilled water. The basal portion (1 to 2 cm) of each cutting was dipped in the solution for 12, 24 and 48 hours. The cuttings were then planted in the nursery bed. Forty five cuttings were used for each treatment in 3 replicates of 15 each. The treatments were as follows:

Concentration of IBA		Dipping period		
		12 hr	24 hr	48 hr
0	ppm	T_0	T_6	T_{12}
50	ppm	T_1	T_7	T_{13}
100	ppm	T_2	T_8	T_{14}
150	ppm	T_3	T_9	T_{15}
200	ppm	T_4	T_{10}	T_{16}
500	ppm	T_5	T_{11}	T_{17}

2.2 Commercial formulations:

Two chemical treatments, namely, Seradix-B (T18) and Rootone (T19) were tried. The directions of manufacturers for use of each commercial formulation were followed before planting them in the nursery. Basal cut was made at the base of cutting which was dipped in the readymade powder removing the excess powder by tapping with finger.

3. Planting:

Nine hundred cuttings (30.0 x 0.75-2.00 cm) in three replicates of 300 each were planted 20 cm deep at an angle of about 60° in well prepared beds at a spacing of 10 x 20 cm. Watering was done as and when required. The cuttings were planted in the nursery areas of Shilli, New Campus and Nihari in three seasons, viz., monsoon, winter and spring.

4. Recording of observations:

Samples of one and two year old cuttings were taken out randomly from the bed and examined for root initiation, callus formation and sprouting after 30,45 , 60, 75 and 90 days.

C. PROPAGATION BY AIR LAYERING:

1. Method of air layering:

Young, healthy and mature shoots were selected and a ring of bark 2.5 to 4 cm in length was removed by giving two cuts. Indole butyric acid (IBA) at 5,000 ppm in lanolin paste was applied on the exposed portion of the shoot with the help of a small brush. This was prepared by thoroughly mixing 100 mg IBA in 20 g pure lanolin paste. Commercial formulations were also applied on the air layers as per directions of the manufacturers. Then a handful of moist sphagnum moss was placed to cover the ringed portion and wrapped with polythene covers of about 20 cm in length and 15 cm in breadth. The two ends were securely tied with twine.

2. Recording of observations:

Observations were recorded after 30, 45, 60 and 90 days of layering. The polethene covers were cut open and layers were examined for the root initiation and the callus formation, alongwith the number of living and non-living layered branches.

D. LAY OUT OF EXPERIMENT:

All the experiments were laid out in randomised block design and analysed statistically for variance and covariance as below

1. Analysis of variance for experimental design:

To find the significance of the difference between the treatments in accordance with the data obtained for each character were analysed on the following model given by Fisher (1938)

$$Pijk = m + Gij + bk + eijk$$

where

m = general mean

Gij = the effect of the treatment ij

bk = the effect of replication k

eijk = error term associated with ijkth observation.

1.1 Analysis of variance:

Source of variation	Degree of freedom	M.S. Observed	M.S. Expected	Variance ratio
Replications	b-1	Mb	Ve + pVr	Mb/Me
Treatment	p-1	Mp	Ve + bVg	Mp/Me
Error	(b-1)(p-1)	Me	Ve	

where:

b= number of replications

p= number of treatments

Vp =Mp = treatments mean square

Vb =Mb = replication mean square

Ve =Me = error mean square

The treatments mean squares were compared against Me(error m.s.) by 'F' test for (p-1), (b-1) (p-1) degree of freedom and replication mean square were tested against Me by 'F' test for (b-1),(p-1) (b-1) degree of freedom at p = 0.05 and p = 0.01.

The standard error of treatments means was equal to $\sqrt{Me/b}$ and standard error difference for comparing two treatment means was $\sqrt{2\ Me/b}$. The critical difference was computed by multiplying the standard error of difference with 'F' value for (b-1) (p-1) degree of freedom at p = 0.05 and p = 0.01.

2. Analysis of covariance for experimental design:

Assumption for covariance are a combination of those for the analysis of variance and linear regression.

For randomized block design with one observation per cell, the following mathematical model was adopted where symbol carried their usual meanings:

$$Y_{ij} = \bar{Y}'' + ti + rj + b\,(X_{ij} - \bar{X}) + eij$$

The analysis of covariance was conducted taking X (1 yr cuttings) as main dependent variable. These

ancillary data was utilized in statistical analysis for making an allowance for the effect of this factor (X) on the estimates of treatment differences and the contributions made by them to the estimated experimental error.

The regression of main variate (Y) on the concomitant variate (X) must come out to be significant so that the adjustments made may be worthwhile. The table given in Appendix - IV B gives the manner for testing the significance of regression by 'F'- test.

The following formula given by Dr. Finney was used for getting the average standard error of the difference between any two treatment means:

$$S.E.\ (diff) = \sqrt{V = \frac{2V_x}{r}\left(1 + \frac{1}{n-1} \times \frac{Tx}{Ex}\right)}$$

where n = no. of treatments compared

r = no. of replications

Tx and Ex = The treatment and error sum of squares respectively

For drawing the bar diagram of the adjusted treatment means the critical difference is calculated as usual i.e. $C.D._{(0.05)} = S.E._{(diff.)} \times t_{0.05}$, for adjusted degree of freedoms.

RESULTS AND DISCUSSION

The results obtained in the present investigation on propagation techniques for raising *Moringa oleifera* Lam. are presented and discussed under the following three heads:-

(i) By seeds

(ii) By cuttings

(iii) By air-layering

1. BY SEEDS:

1.1 Effect of storage containers on the germination of seed:

The seeds after drying were kept in open tray (T_1), closed tin (T_2), gunny bag (T_3) and plastic jar (T_4) and sown in the field after a storage period of one month. The observations and analysis of variance for this character are presented in Table-1, Appendix-IA and Fig- 3A.

Table 1

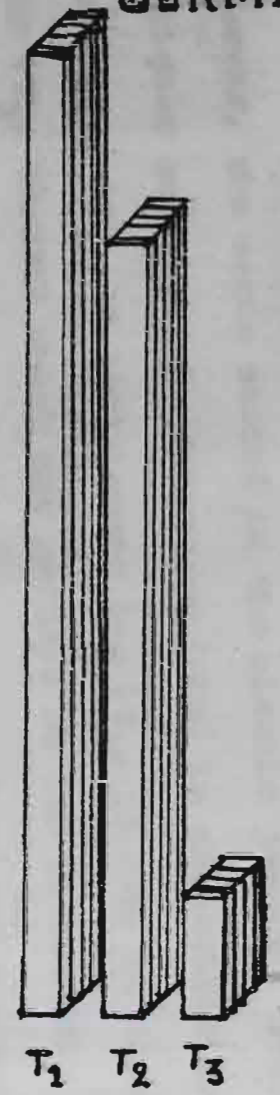
Effect of storage container on seed germination

Treatments		Mean	Germination percentage
Plastic jar	(T_4)	60.00	60.00
Open tray	(T_1)	56.66	56.66
Gunny bag	(T_3)	53.33	53.33
Closed tin	(T_2)	43.33	43.33

Analysis of the data showed that the effect of storage container on seed germination was not significant.

FIG.3-A. EFFECT OF STORAGE CONTAINER ON SEED GERMINATION

FIG.3-B. EFFECT OF STORAGE PERIOD ON SEED GERMINATION



Analysis of the data showed that the difference between the various types of containers used in this experiment was non-significant, hence all types of containers were equally good for storage purpose. However, the seeds stored in the plastic jar (T_4) registered a higher germination percentage (60%) in comparison to open tray (T_1, 56.66%), gunny bag (T_3, 53.33%) or closed tin (T_2, 43.33%) which may perhaps be due to better protection provided by plastic covering of jar against climatic variations and fungal or pest attack.

1.2. Effect of storage period on seed germination:

The air dried seeds stored in open tray were sown in the nursery after a period of one month in July (T_1), after two months in August (T_2) and after three months in September (T_3). The observations and the analysis of variance for this character are presented in Table-2, Appendix IB and Fig- 3B.

Table 2

Effect of storage period on seed germination

Treatments	Mean	Bar diagram	Germination percentage
After 1 month i.e. July sowing (T_1)	120		60
After 2 month i.e. August sowing (T_2)	96		48
After 3 month i.e. September sowing (T_3)	15		7.5
S.E.$_{(diff)}$			13.38
C.D.$_{(0.01)}$			49.59

Plate-I:- Seedlings damaged by frost.

Plate-II:- A healthy seedling of three month old.

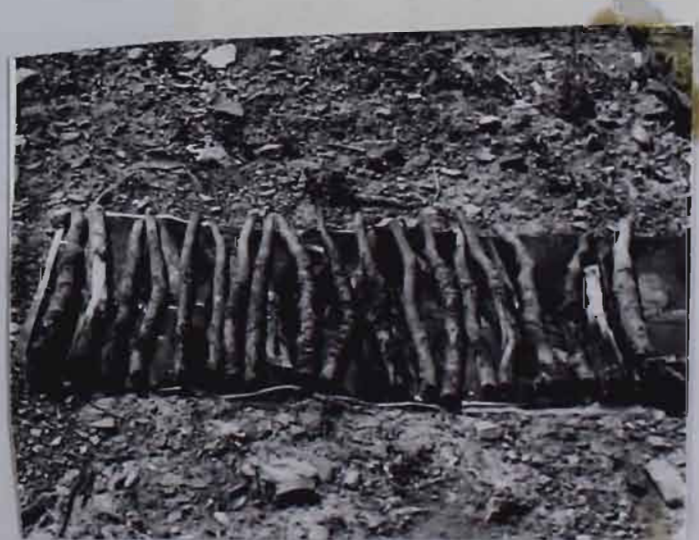


Plate-III:- Cuttings infested with insects and fungal attack.

Analysis of the data revealed that the seeds sown after one month from the date of harvesting (T_1) gave highest germination (60%) as compared to other treatments. Sowing of seeds after two months (T_2) also gave significantly higher germination (48%) than the seed sown after three months (T_3, 7.5%). This indicates that sowing in the month of July within one month of harvest is best suited for this species and it should not be kept in storage for a period of more than two months as the germination percentage declines significantly thereafter. In case of September sowing the seedlings were injured by frost (Plate-I).

1.3 Response of seeds to normal sowing:

Emergence of seedlings in the nursery beds was recorded on 12th day after sowing of seeds. The emergence of seedlings continued for about 30 days. The total germination percentage registered in normal sowing of untreated seeds was 64 per cent. All seedling in normal sowing were healthy and were not infested and attacked by fungal and insects respectively (Plate-II). Under the laboratory conditions seedlings emerged comparatively earlier on 10th day and germination percentage was 80.

Seth et al., (1962) reported that germination in Moringa oleifera seeds commenced from the 9th day onwards which is slightly earlier than the time taken for germination in our experiments. Some authors have also reported a slighhly higher germination percentage

(66%). These differences in germination time and percentage may be primarily due to locational and climatic variations and difference in other experimental conditions.

1.4. Effect of pre-sowing treatments on seed germination, height and diameter of seedlings:

1.4.a. Effect of seed germination:

The observations made for these treatments and analysis of variance for these characters are presented in Table-3, Appendix-IIA and Fig-4A.

Table-3

Effect of presowing treatments on seed germination

Treatments	Mean	Bar diagram	Germination percentage
Control (T_1)	120.00		64.86
24 hour water soaking (T_6)	93.33		50.44
48 hour water soaking (T_7)	86.66		46.84
Soaking in 0.1% HCl (T_2)	26.66		14.41
Soaking in 0.2% HCl (T_3)	6.66		3.66
Soaking in 0.5% HCl (T_4)	6.66		3.66
Soaking in 1% HCl (T_5)	0.00		0.00
S.E.(diff.)			16.15
C.D.(0.01)			49.34

A perusal of the data will show that the seeds which were untreated (control, T_1) gave the highest germination (64.86%) among all the treatments but no

FIG-1A. EFFECT OF PRESOWING TREATMENTS ON SEED GERMINATION

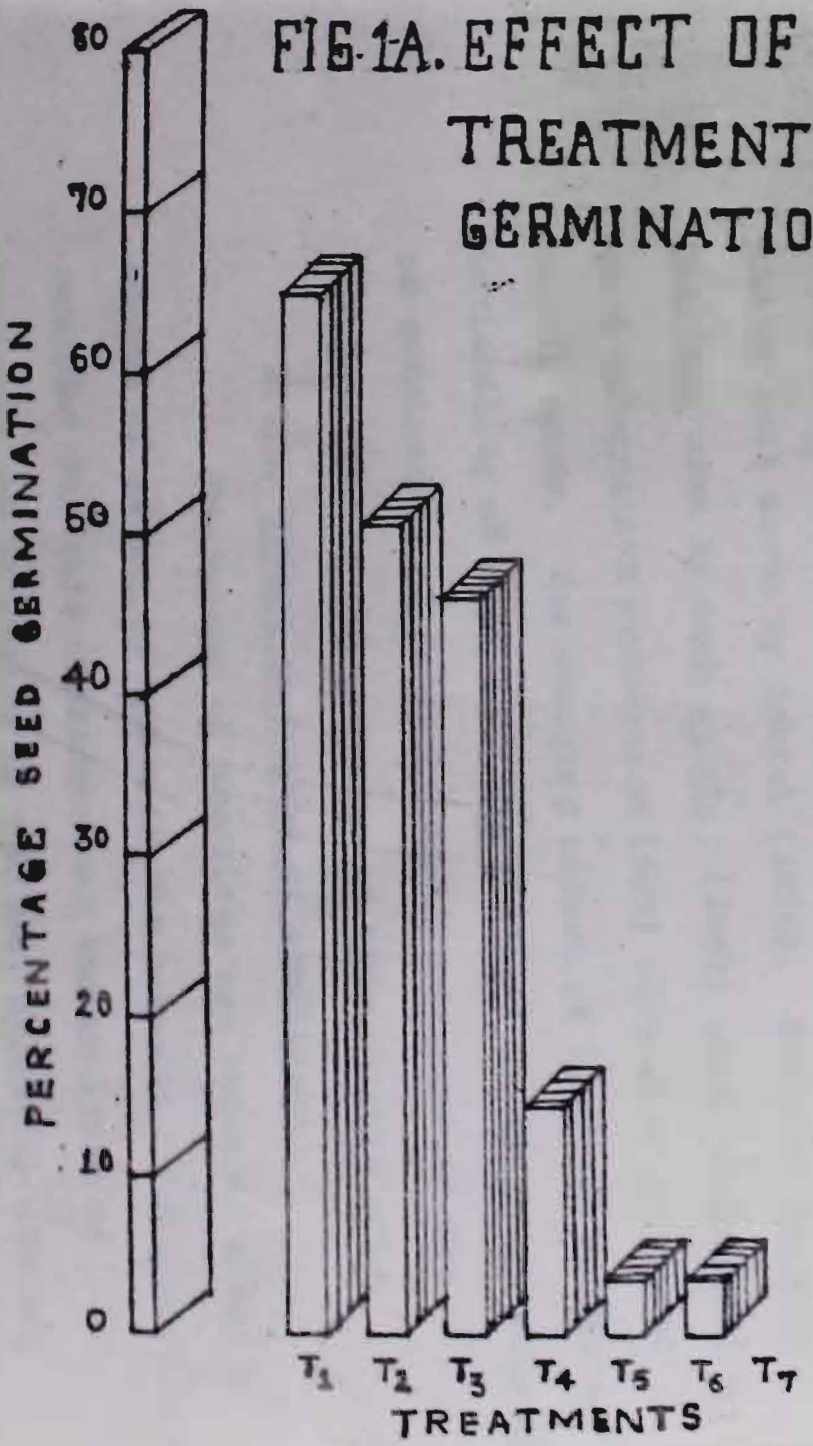
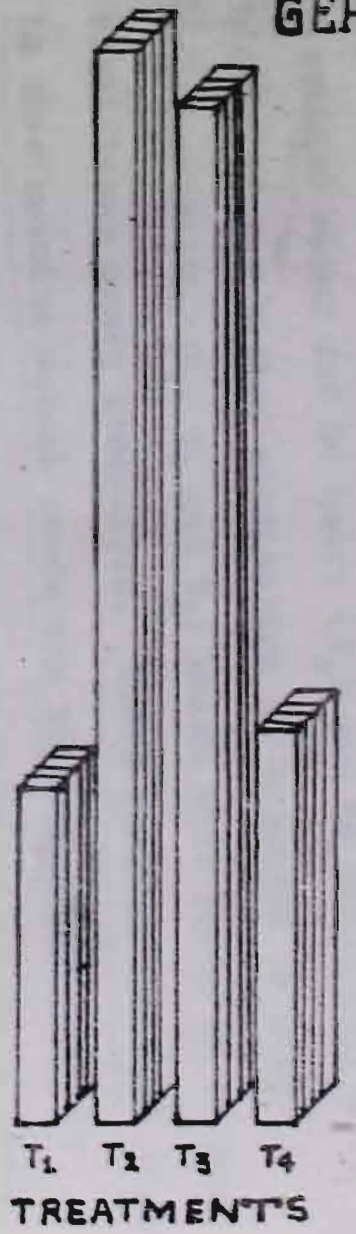


FIG-1B. EFFECTOF DEPTH OF SOWING ON SEED GERMINATION



significant difference was found to occur in germination between T_1, T_6 and T_7, though T_1 showed significantly higher germination when compared with the acid treatments (T_2, T_3, T_4 and T_5). Similarly, soaking of seeds in distilled water for 24 hours (T_6) and 48 hours (T_7) gave significantly higher germination as compared to acid treatments (T_2, T_3, T_4 and T_5) which were found to be non significant among themselves. These results indicate that in this species normal seeds can be sown after harvest as such without any treatment and treating of these seeds with distilled water or acid gives no additional advantage, rather it has a deleterious effect on germination. Similar harmful effect of soaking of seeds in water was found to occur in Robinia pseudoacacia by Troup (1921) and in teak seeds by Debral (1976). Seeds of Moringa oleifera sown by Seth et al., (1962) which registered a good germination percentage (66%) were also untreated normal seeds. The damaging effect of acid may be due to inviability of embryo or the blockage of metabolic process of germination or degradation/inactivation of the metabolities in the presence of hydrochloric acid.

1.4.b. Effect on height of seedlings:

The height of seedlings was recorded after 3 months of sowing of seeds in the nursery. The observations recorded for this character and the analysis of variance are presented in Table-4, Appendix- IIB and Fig-2A.

Table-4

Effect of pre-sowing treatments on height of seedlings

Treatments		Average height (in cms)	Bar diagram
Control	(T_1)	11.33	
24 hour water soaking	(T_6)	9.50	
48 hour water soaking	(T_7)	8.96	
Soaking in 0.1% HCl	(T_2)	6.33	
Soaking in 0.2% HCl	(T_3)	2.36	
Soaking in 0.5% HCl	(T_4)	1.73	
Soaking in 1% HCl	(T_5)	0.00	
S.E.$_{(diff.)}$		1.457	
C.D.$_{(0.01)}$		3.175	

The perusal of the data will reveal that the control (T_1) gave highest average shoot length among all the treatments. There was no significant difference in average shoot length among T_1, T_6 and T_7 treatments, though T_1 had significantly higher shoot length when compared with T_2, T_3, T_4 and T_5 treatments. Similarly, T_6 and T_7 showed significantly more shoot length as compared to T_2, T_3, T_4 and T_5 treatments. Treatments T_1, T_6, and T_7, T_6 and T_7, T_7 and T_2, T_3, T_4 and T_5 did not differ significantly among themselves.

As in case of seed germination, the untreated seed (control, T_1) appears to be the best among all the treatments and as such is more suited for development of taller seedlings. There appears to be no advantage of pre-treatment of seeds with water or HCl as these two treatments have been found to result in lower shoot length. No reference on this aspect could be available in the literature hence it is difficult to explain this phenomenon at the present stage. It may probably be due to in-activation of growth promoting hormones/ enzymes by HCl in the earlier stages of the seedlings.

1.4.c. Effect of diameter of seedlings:

The diameter of seedlings was recorded at ground level after 3 months of sowing of seeds. The observation made on this parameter and the analysis of variance are reported in Table-5, Appendix-IIC and Fig-2B.

Table-5

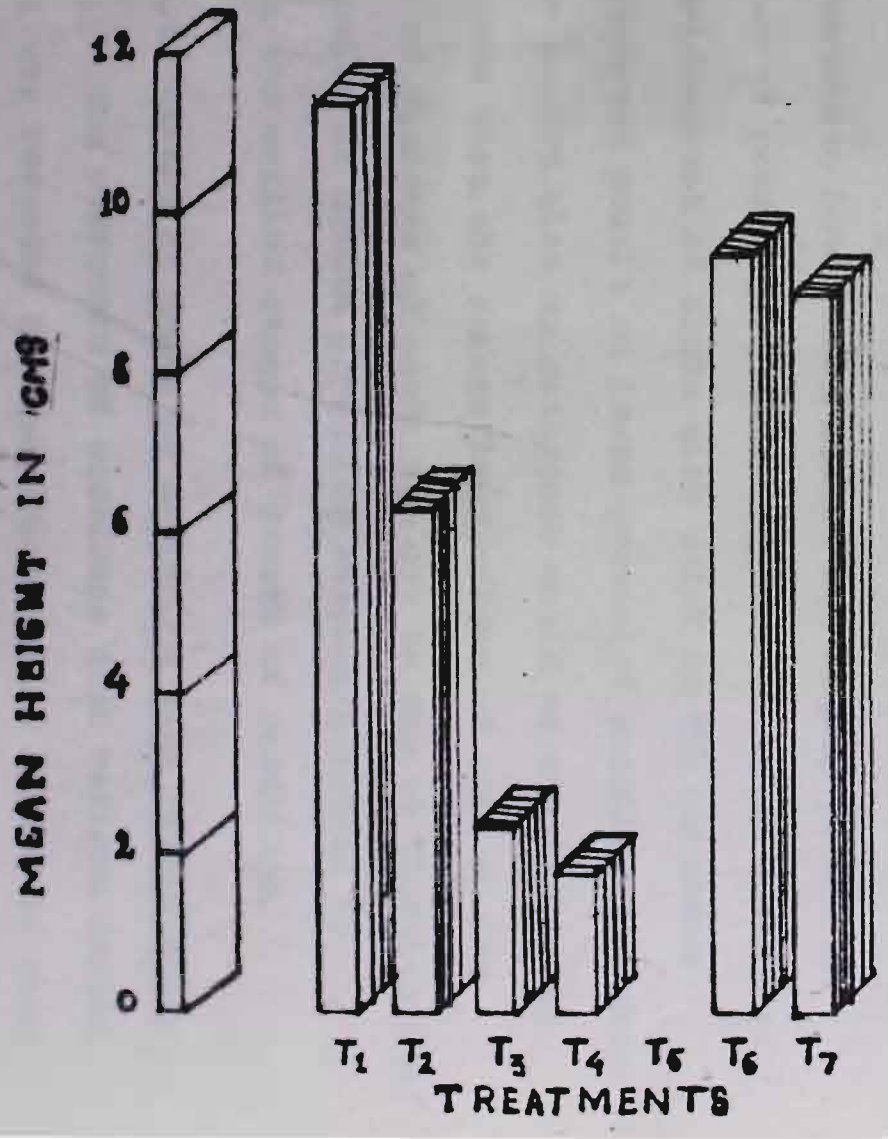
Effect of pre-sowing treatments on diameter growth of seedlings.

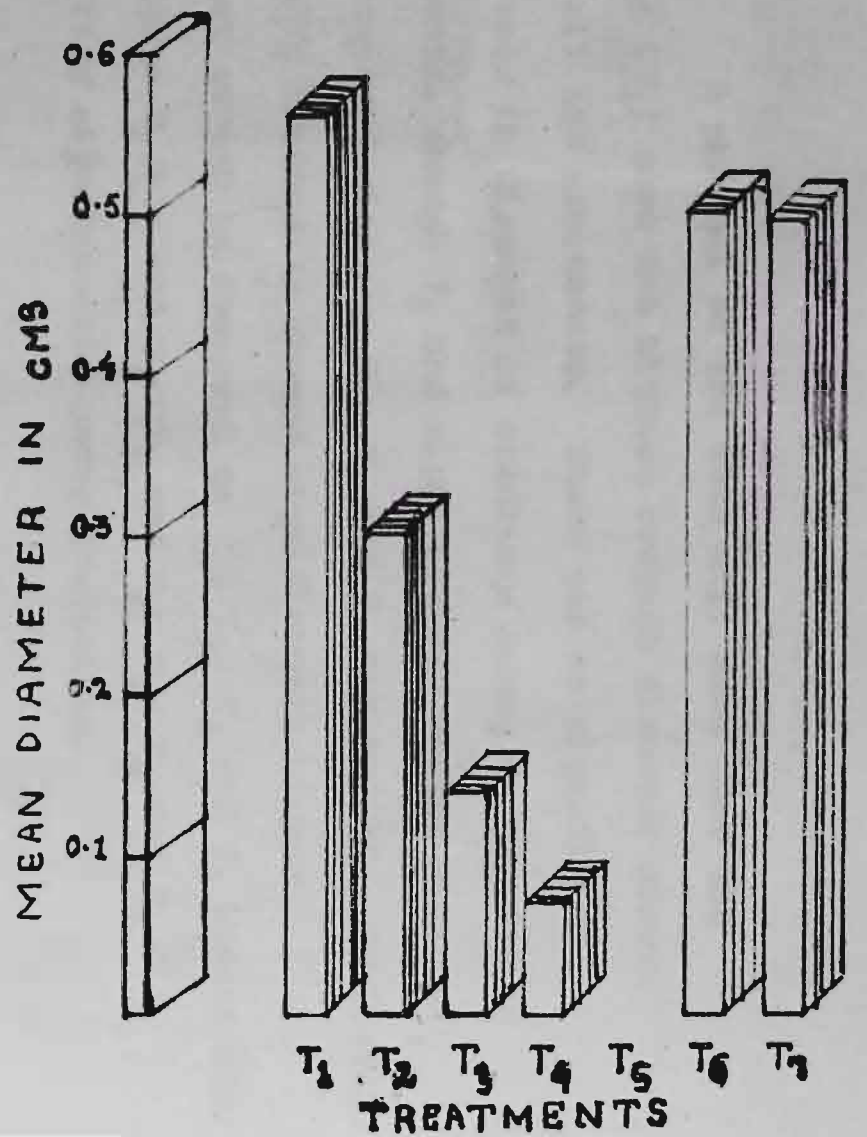
Treatments		Average diameter (in cms)	Bar diagram
Control	(T_1)	0.363	
24 hour water soaking	(T_6)	0.303	
48 hour water soaking	(T_7)	0.496	
Soaking in 0.1% HCl	(T_2)	0.303	
Soaking in 0.2% HCl	(T_3)	0.140	
Soaking in 0.5% HCl	(T_4)	0.073	
Soaking in 1% HCl	(T_5)	0.000	
S.E.(dil)		0.088	
		0.271	

FIG. 2. EFFECT OF PRESOWING TREATMENTS ON:

A. HEIGHT OF SEEDLING

B. DIAMETER OF SEEDLING





A perusal of the data will show that the control (T_1) gave the highest average diameter growth among all the treatments. There was no significant difference in diameter of seedlings among T_1, T_2, T_6 and T_7 treatments, though T_1 had significantly higher diameter when compared with T_3, T_4 and T_5 treatments. Similarly, T_2, T_6 and T_7 treatments showed significantly higher diameter growth as compared to T_3, T_4 and T_5 treatments. Treatments T_1, T_2, T_6 and T_7, T_2, T_3 and T_4, T_3, T_4 and T_5 did not differ significantly among themselves.

As in case of aforesaid two parameters (germination percentage and shoot length), the untreated seeds (control, T_1) appears to be the best amongst all the treatments hence best suited for higher growth of diameter of seedlings. There appears to be no advantage of pre-treatment of seeds with water or HCl as these pre-treatment result in lower growth of seedling diameter. On this aspect also no reference could be available but it appears that the deleterious effect of acid on the growth of diameter of seedlings may be due to inactivation/ destruction of growth promoting enzymes/hormones by acid in the earlier stages of growth of seedlings.

1.3. Effect of depth of sowing on seed germination:

The emergence of seedlings from various depths of soil was recorded for two months after sowing of seed in the first week of July. The observations recorded on

this parameter and the analysis of variance are presented in Table-6, Appendix-III and Fig- 1B.

Table-6

Effect of depth of sowing on seed germination

Treatments depth of sowing (in mm)	Mean	Bar diagram	Germination percentage
10 mm (T_2)	36.66	|	66.65
15 mm (T_3)	31.66	|	57.66
20 mm (T_4)	13.33	|	24.23
5 mm (T_1)	11.66	|	21.20
S.E.(diff.)	4.858		
C.D.(0.01)	18.008		

A perusal of the data revealed that the seeds sown at 10 mm depth (T_2) gave the highest (66.65%) germination of seeds among all the treatments. There was no significant difference in germination between 10 mm (T_2) and 15 mm (T_3) treatments. However, T_2 treatment had significantly higher germination when compared with T_4 and T_1 treatments. Similarly, T_3 treatment also had significantly higher germination as compared to T_4 and T_1 treatments which were non-significant between themselves.

Singh et al., (1973), recorded a higher percentage of germination in Kail (Pinus wallichiana) seeds at 15 mm soil depth. In this experiment the maximum percentage of

germination was recorded at a soil depth of 10 mm instead of 15 mm. Shallow as well as deep sowing (than 10 mm) greatly reduced the germination. This can be attributed to poor formation of roots of the seedlings in shallow sowing whereas in the deeper sowing, the radical of the seedlings remains embedded too deep and is not able to emerge out.

2. BY CUTTINGS:

2.1 Effect of different plant regulators on rooting of branch cuttings:

As mentioned under material and methods, the one and two year old branch cuttings after treating with plant regulators were planted in three seasons, viz., monsoon (July, August, September), winter (November and December), spring (February and March).

It was observed that all the cuttings, whether treated or untreated, failed to root when planted in rainy season or in winter.

In monsoon the growth response was extremely poor. Almost all the cuttings were found severely attacked and heavily infested with insects and pests, prominent amongst which were maggots, spring tails, larvae of arthropods, mites and thrips. These cuttings were also attacked heavily by disease causing fungi, mainly Macrophoma, Fusarium and Trichoderma species. This resulted in heavy mortality of cuttings which subsequently decayed and died (Plate - III).

The cuttings planted during winter months also showed a poor growth response. In a few cuttings sprouting was observed but without formation of roots. These cuttings also died subsequently, the poor growth response and poor root formation in these cuttings can be attributed to the factors like light, temperature, water, humidity and aeration which are unfavourable during these months.

The third set of cuttings which were planted during spring showed a good growth response and the observations on their sprouting and rootings were recorded up to three months of planting. These observations and their analysis of variance are presented in Table-7, Appendix-IV- A to B.

The analysis of covariance of the data revealed that the regression coefficient of 2 yr.cuttings (Y) on one year cuttings (X) is highly significant at 0.05 level of significance leading to the conclusion that the variability in the first year cuttings had significant effect on two year cuttings as tested by applying 'F' test. This necessiated the adjustment of the treatment means as given in table in Appendix-IV-D.

The average critical difference of any two adjusted treatment means is obtained by using the formula given by Dr. Finney (mentioned in the chapter material and methods).

Table-7

Effect of different plant regulator treatments on rooting of cuttings.

Treatments	Adjusted Mean $\bar{Y}i=\bar{Y}-b(\bar{X}i-\bar{X})$	Bar diagram	Rooting percentage
T_7	6.54		43.60
T_6	5.54		36.93
T_2	4.54		30.26
T_9	4.54		30.26
T_{18}	4.54		30.26
T_{19}	4.54		30.26
T_5	3.88		25.86
T_1	3.55		23.66
T_3	3.54		23.60
T_0	3.22		21.46
T_4	2.87		19.13
T_{11}	2.54		16.93
T_{10}	2.21		14.73
T_8	1.87		12.46
T_{13}	1.54		10.26
T_{15}	1.54		10.26
T_{14}	1.20		8.00
T_{16}	1.20		8.00
T_{12}	0.54		3.60
T_{17}	0.54		3.60
S.E.(diff.)	x $t_{0.05}$, error d.f.		0.36
C.D.			1.176

perusal of the data showed that treatment T_7 gave significantly more rooting in comparison to other treatment except T_6. Treatments T_7 and T_6 were found to be non significant between each other. Treatment T_6 also gave significant results when compared with treatments T_5, T_1, T_3 T_0, T_4, T_{11}, T_{10}, T_8, T_{13}, T_{15}, T_{14}, T_{16}, T_{12} and T_{17} but was found to be non significant when compared with T_7, T_2, T_9, T_{18} and T_{19} treatments. Similarly treatments T_2, T_9, T_{18}, T_{19}, T_5, T_1 and T_3, T_5, T_1, T_3, T_0 and T_4, T_1, T_3, T_0, T_4 and T_{11}, T_0, T_4, T_{11} and T_{10}, T_4, T_{11}, T_{10} and T_8, T_{11}, T_{10}, T_8, T_{13} and T_{15}, T_{10}, T_8, T_{13}, T_{15}, T_{14} and T_{16}, and T_{13}, T_{15}, T_{14}, T_{16}, T_{12} and T_{17} were found to be non significant among each other.

As reported by Hitchcock and Zimmerman (1930) Brandon (1939), Grigorov and Malacom (1956), Hamoda (1958), Sood (1978) and many other workers, season plays a paramount role in rooting of stem cuttings. Some cuttings root throughout the year, while others are seasonal. Temperature influences the formation of callus and also the initiation and development of root system in stem cuttings. From our observations it appears that Moringa oleifera is a seasonal tree, the branch cuttings of which should be planted during spring season (February-March).

Softwood cuttings of many trees and shrubs root better in spring (Hartmann and Kaock, 1958). The seasonal changes in the rooting response of cuttings have been

ascribed to by nature of cuttings (Nanda, 1970), changes in food forming substances (Klein, 1953) or to physiological status (Wells, 1963) or to changes in the endogenous content of growth substances (Tyes, 1957).

As regards the effect of different plant regulators on rooting of cuttings, IBA 50 ppm, 24 hour dip was found to be the best giving 43.60% rooting in branch cuttings.

No reference could be available to indicate the effect of plant regulators on the rooting of branch cuttings of this species but that initiation of rooting is stimulated by application of growth hormones and plant regulators has been shown by many workers in several species of forest trees. Ghosh and Bhatnagar (1977) observed that 200 ppm of IBA was best for rooting of Populus gamblei cuttings. Mahlawi et al., (1976) reported better rootings of olive wood cuttings with the application of IBA (5000 ppm, 6 second dip). Rooting was induced in the cuttings of Poinsettia pulcherrima by treating with IBA at 5-10 ppm. Bhattacharya and Bhaduri (1959) obtained better rooting of Bougainvillea glabra with 1000 and 5000 ppm of IBA. Singh (1956) reported vegetative propagation of Kigelia pinnata by inducing rooting on hardwood cuttings with 20 ppm IBA for 12 hour treatment.

2.2 Effect of plant regulators on rooting response one and two year old branch cuttings:

One and two year old branch cuttings with similar treatments as mentioned in 2.1 were planted during February-March, 1979 to determine the effect of plant regulators on the rooting response of these cuttings. The observations recorded upto 3 months are presented in Table-8a and by Appendix-V-A-B for one and two year cuttings, respectively. (Fig. 4).

Perusal of the data shows that treatment T_{18}, gave significantly more rooting in comparison to other treatments except T_1, T_0, $T_7$and T_6. No significant difference was found among T_{18}, T_1, T_0, T_7 and T_6; T_1 T_0, T_7, T_6 T_{19}, T_9, T_5, T_3, T_{11},and T_2 and T_{10}; T_7, T_6, T_{19}, T_9, T_5, T_3, T_{11}, T_2, T_{10}, T_4, T_8, T_{13}, T_{15}, T_{14}, T_{16}, T_{12} and T_{17}. Similarly T_1 and T_0 gave significantly more rooting except T_{18}, T_7 and T_6 which are not significant amongst each other, (Table-8a).

A perusal of the data showed that in case of two year old cuttings T_7 gave significantly more rooting as compared to the other treatment except T_6 and T_{18}. The rooting of T_{19}, T_9, T_1, and T_2 treatments were found to be initiate more rooting than T_0,T_5,T_3,T_{11},T_4,T_{10},T_8,T_{13},T_{15}, T_{14},T_{16},T_{12} and T_{17} treatments. Treatments T_7,T_6 and T_{18}; T_{19}, T_9, T_1,T_2, T_0, T_5 and T_3; T_0,T_5,T_3,T_{11},T_4 and T_{10}; T_{11}, T_4, T_{10} and T_8; T_4,T_{10}, T_8, T_{13} and T_{15}; T_{10}, T_8,T_{13},T_{14} and T_{16}; T_8, T_{13}, T_{15}, T_{14}, T_{16}, T_{12} and T_{17} were found to be non significant among each other.

FIG.4. EFFECT OF GROWTH REGULATERS ON THE ROOTING OF 1 AND 2 YEAR OLD BRANCH CUTTINGS

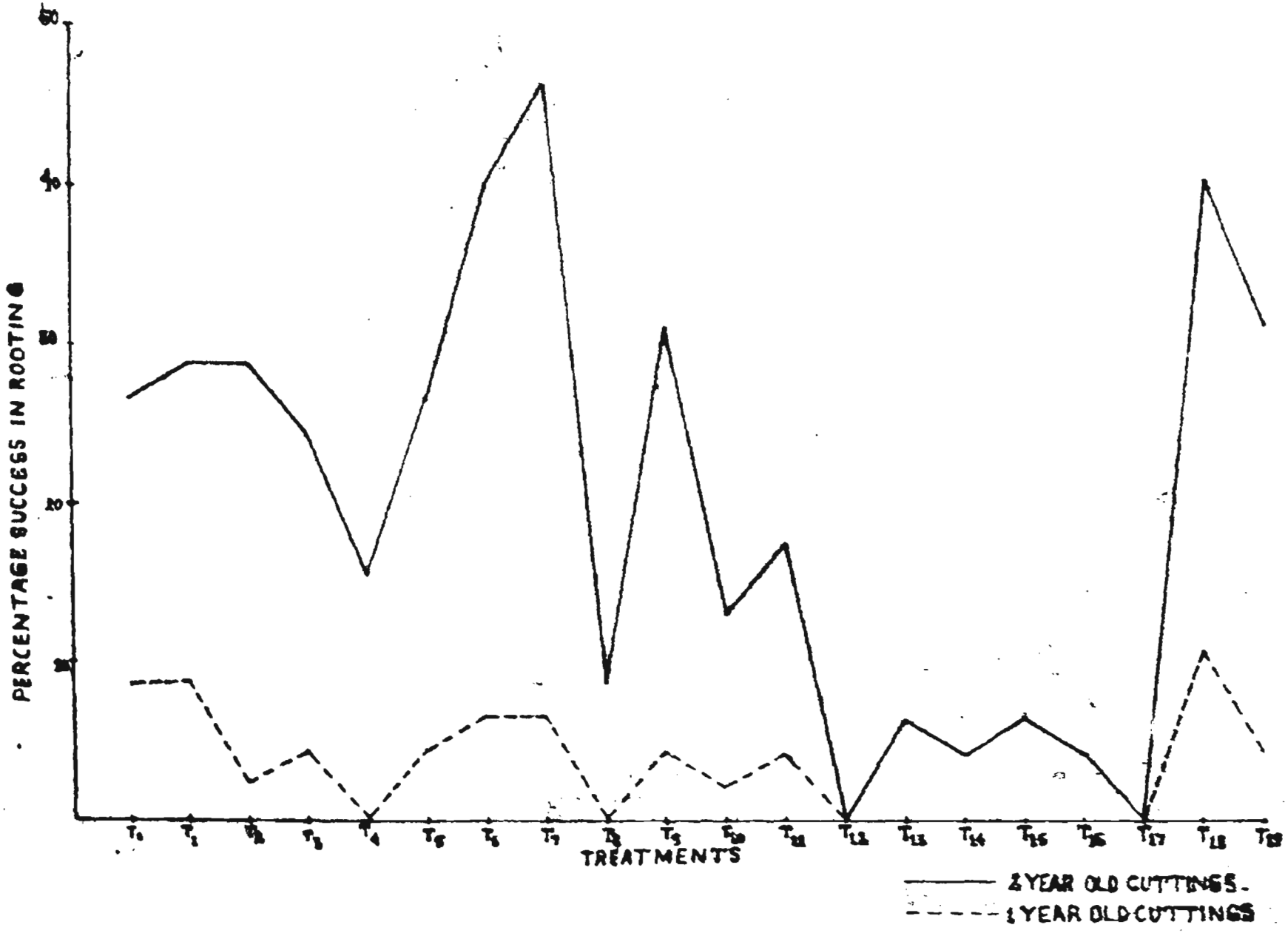


Table-8a

Effect of different plant regulator treatments on rooting of 1 year cuttings.

Treatment	Mean (1 year)	Bar Diagram	Rooting percentage
T_{18}	2.00		13.33
T_1	1.33		8.86
T_0	1.33		8.86
T_7	1.00		6.66
T_6	1.00		6.66
T_{19}	0.66		4.40
T_9	0.66		4.40
T_5	0.66		4.40
T_3	0.66		4.40
T_{11}	0.66		4.40
T_2	0.33		2.20
T_{10}	0.33		2.20
T_4	0.00		0.00
T_8	0.00		0.00
T_{13}	0.00		0.00
T_{15}	0.00		0.00
T_{14}	0.00		0.00
T_{16}	0.00		0.00
T_{12}	0.00		0.00
T_{17}	0.00		0.00
S.E. (diff.)			0.467
C.D. (0.05)			1.1514

Table-9b

Effect of different plant regulator treatments on rooting of 2-year cuttings

Treatment	Mean (2 year)	Bar diagram	Rooting Percentage
T_7	7.00		46.66
T_6	6.00		40.00
T_{18}	6.00		40.00
T_{19}	4.66		31.06
T_9	4.66		31.06
T_1	4.33		28.88
T_2	4.33		28.88
T_0	4.00		26.66
T_5	4.00		26.66
T_3	3.66		24.40
T_{11}	2.66		17.73
T_4	2.33		15.53
T_{10}	2.00		13.33
T_8	1.33		8.86
T_{13}	1.00		6.66
T_{15}	1.00		6.66
T_{14}	0.66		4.40
T_{16}	0.66		4.40
T_{12}	0.00		0.00
T_{17}	0.00		0.00
$S.E._{(diff.)}$			0.565
$C.D._{(0.05)}$			1.456

The aforesaid observations indicate that higher rooting response to plant regulator treatment was shown by 2 year old branch cuttings than by one year old branch cuttings.

Reference on similar studies could not be available in the literature but some studies have been made on rooting response of cuttings with age of the mother tree. Age of the tree greatly influences the rooting. Jusufer (1965) reported that the rooting response of cuttings decreases with the age of mother tree. Marcavillaca and Montaldi (1963) working with Eucalyptus found that cuttings taken from old trees did not root at all. Nelson and Pepper (1966) attributed higher rooting of juvinile cuttings to higher content of co-factors. It was considered that water soluble growth inhibitors accumulate with age and prevent old cuttings to root. Besides age, the other factors like the nutrient status of the cuttings, tissue characteristics, growth promotors and inhibitors all affect the differentiation of roots.

In this study maximum rooting response inspite of all treatments was limited to 46.66 per cent which cannot said to be a successful operation. The shyness of Moringa cuttings to root satisfactorily may be attributed either to mechanical barrier, inadequacy of endogenous auxins, inadequacy of nutrition or to the presence of inhibitors. Nevertheless, further investigations are

required to be carried out to improve the success of branch cuttings as a vegetative method of propagation in this species.

3. AIR LAYERING:

Observations on rooting of layers were recorded upto 90 days after air layering. The results are summarised in Table-9.

Table-9

Effect of different plant regulator treatments on rooting of air layers of Moringa oleifera Lam.

Treatment		Rooting percentage
IBA 5,000 ppm	(T_1)	5.0
Seradix B	(T_2)	0.0
Rootone	(T_3)	0.0
Control	(T_0)	0.0

The results indicated that there was no rooting at all in the untreated layers (control), as well as in those layers which were treated with commercial formulations (T_2 and T_3). Very little success (5%) was obtained in the air layers treated with IBA 5000 ppm (T_1).

Rao (1953) has indicated the possibility of propagating Moringa oleifera by air layering but in the studies a very poor response was obtained by this method. There is, however, tendency to form roots when induced by a

growth regulator (IBA 5000 ppm in lanolin paste) but this needs further investigations to prove the success of this method. Quite possible use of higher concentrations of IBA or any other growth regulator which have not been tried and may result in greater success of this method.

SUMMARY AND CONCLUSIONS

The present investigation on the standardization of propagation techniques of *Moringa oleifera* Lam. in sub-Himalayan region were carried out in the Department of Forestry, Himachal Pradesh Krishi Vishva Vidyalaya during 1978-79. The propagation by means of seeds, branch cuttings and air layering were tried. The results and conclusions drawn are summarised below-

1- Freshly extracted seeds were stored in four types of containers viz., open tray, air tight tin, gunny bag and plastic jar. Highest germination percentage (60%) was shown by the seeds stored in plastic jar, but the difference between the containers was statistically non-significant. Thus seeds can be stored in any of the above four types of containers at room temperature.

2- The seeds sown after one month storage (July) gave highest germination (60%) as compared to two months (August, 48%) and three months (September, 7.5%) storage period. The germination percentage goes on declining progressively with increase in storage period. *Moringa oleifera* seeds should be sown in July and should not be stored for a period of more than two months if satisfactory germination is to be desired.

3- Freshly extracted seed sown in July within one month of the harvest registered a germination of 64 per cent. Emergence of seedlings commenced on 12th day and continued for about 30 days after sowing.

4- The seeds pre-treated with hydrochloric acid (0.1 to 1%) registered a germination percentage of 0.0 to 14.41 in comparison to 46.84 and 50.44% germination registered by pre-soaking of seeds in water for 24 and 48 hours respectively The untreated seeds showed highest germination percentage (64.86%). The untreated seeds also showed maximum height and diameter growth of seedlings. The seeds of Sohanjna should, therefore, be sown as such without giving any pre-treatment.

5- Sowing of Moringa seeds at 5,10,15 and 20 mm soil depths showed that both shallow as well as deep sowing appreciably decrease the germination percentage. The optimum depth for sowing the seed was observed at 10 mm.

6- One and two year old branch cuttings (30 cm x 0.75 to 2.00 cm) failed to form roots when planted during monsoon or winter season. The best time for planting of cuttings was observed to be spring season (February- March). Pre-treatment of branch cuttings with IBA (50 ppm, 24 hours)

induced higher rooting (43.60%) as compared to untreated cuttings (21.46%). Hence to achieve better success, the cuttings of Sohanjna should be planted only after pre-treatment with IBA.

7- Two year old cuttings were found to give a higher response (46.66%) of rooting with IBA (50 ppm for 24 hours) as compared to one year old cuttings (13.33% with Seradix-B). Thus for vegetative propagation of Moringa two year cuttings must be preferred to one year old branch cuttings.

8- Air layering was not found to be a successful method of vegetative propagation of this species and a very poor (5%) response was recorded in this method after treatment of layers with IBA 5,000 ppm in lanolin paste. More studies involving other air layer inducing hormones are required to be conducted for achieving more success in this method.

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* Original not seen.

APPENDIX-I A

Analysis of variance of data on the effect of storage container on seed germinations.

Source of variation	d.f.	S.S.	M.S.	Calculated F value	Tabulated F value at 5%	Tabulated F value at 1%
Replication	2	66.67	33.335	0.2727		
Treatment	3	466.67	155.556	1.2727	4.76	9.78
Error	6	733.33	122.22			

Non significant at 5 per cent level of significance

APPENDIX-I B

Analysis of variance of data on the effect of storage period on seed germination.

Source of variation	d.f.	S.S.	M.S	Calculated F value	Tabulated F value at 5%	Tabulated F value at 1%
Replication	3	752.917	250.97			
Treatment	2	42254.17	21127.08	112.99**	5.14	10.92
Error	6	1121.833	186.97			

** significant at 1% level of significance.

APPENDIX-II A

Analysis of variance of data on the effect of pre-sowing treatments on seed germination.

Source of variation	d.f.	S.S.	M.S.	Calculated F value	Tabulated F value	
					5%	1%
Replication	2.	55.998	27.999			
Treatment	6	44723.809	7453.9681	57.143**	3.00	4.82
Error	12	1565.336	130.444			

** Significant at 1 per cent level.

APPENDIX-II B

Analysis of variance of data on height growth of seedlings after 3 months.

Source of variance	d.f.	S.S.	M.S.	Calculated F value	Tabulated F value	
					5%	1%
Replication	2	4.98	2.49	0.5452		
Treatment	6	349.69	58.282	12.7626**	3.00	4.82
Error	12	54.80	4.5666			

** Significant at 1 per cent level

APPENDIX-II C

Analysis of variance of data on the diameter size of the seedlings after 3 months.

Source of variation	d.f.	S.S.	M.S.	Calculated F value	Tabulated F value	
					5%	1%
Replication	2	0.0121	0.0060			
Treatment	6	0.9489	0.15815	13.357**	3.00	4.82
Error	12	0.1421	0.01184			

** Significant at 1 per cent level

APPENDIX-III

Analysis of variance of data on effect of depth of sowing on seed germination.

Source of variation	d.f.	S.S.	M.S.	Calculated F value	Tabulated F value	
					5%	1%
Replication	2	54.17	27.085	.7647		
Treatment	3	1450.00	483.333	13.647**	4.76	9.78
Error	6	212.50	35.416			

** Significant at 1 per cent level.

APPENDIX-IV A

Analysis of variance and covariance, table.

Source of variation	d.f.	SSY	SP	XY	SSX	MSY	Fc	Ft 0.05	Ft 0.01
Replications	2	0.43	0.31	0.23					
Treatment	19	260.32	57.46	18.93		13.70	28.54**	1.85	2.41
Error	38	18.23	11.69	11.77		0.48			

** Significant at 1 per cent level of significance

APPENDIX- IV B

Analysis of variance of Y (2 yr.).

Source of variation	d.f.	S.S.	M.S.	Fc	Ft 0.05	Ft 0.01
Regression	1	11.61	11.61	64.5**	4.10	7.38
Error	37	6.62				

** Significant at 1 per cent level of significance.

APPENDIX-IV C

Adjusted S.S. and analysis of reduced variance

Source of Variation	d.f.	S.S.	M.S.	Fc	Ft	
					0.05	0.01
Treatment	19	116.17	6.11	33.97**	1.87	2.41
Error	37	6.62	0.18			

** Significant at 1 per cent level of significance.

APPENDIX-IV D

Adjusted treatment mean.

Treatment	$\bar{X}i$	$\bar{X}i-\bar{X}(0.54)$	byx($\bar{X}i-\bar{X}$) (y=0.99)	$\bar{Y}i$ Main variate mean	Adjusted mean $\bar{Y}i=\bar{Y}i-b(\bar{X}i-\bar{X})$
T_0	1.33	0.79	0.78	4	3.22
T_1	1.33	0.79	0.78	4.33	3.55
T_2	0.33	-0.21	-0.21	4.33	4.54
T_3	0.66	0.12	0.12	3.66	3.54
T_4	0.00	-0.54	-0.54	2.33	2.87
T_5	0.66	0.12	0.12	4.00	3.88
T_6	1.00	0.46	0.46	6.00	5.54
T_7	1.00	0.46	0.46	7.00	6.54
T_8	0.00	-0.54	-0.54	1.33	1.87
T_9	0.66	0.12	0.12	4.66	4.54
T_{10}	0.33	-0.21	-0.21	2.00	2.21
T_{11}	0.66	0.12	0.12	2.66	2.54
T_{12}	0.00	-0.54	-0.54	0.00	0.54
T_{13}	0.00	-0.54	-0.54	1.00	1.54
T_{14}	0.00	-0.54	-0.54	0.66	1.20
T_{15}	0.00	-0.54	-0.54	1.00	1.54
T_{16}	0.00	-0.54	-0.54	0.66	1.20
T_{17}	0.00	-0.54	-0.54	0.00	0.50
T_{18}	2.00	1.46	1.46	6.00	4.54
T_{19}	0.66	0.12	0.12	4.66	4.54

APPENDIX-IV A

Analysis of variance of data on the effect of different plant regulation treatments on rooting of one year old branch cuttings.

Source of variation	d.f.	S.S.	M.S.	Calculated F value	Tabulated F value	
					5%	1%
Replication	2	0.23	0.12	0.40		
Treatment	19	18.93	0.99	3.33**	1.85	2.41
Error	38	11.77	0.30			

** Significant at 1 per cent level of significance

APPENDIX- V B

Analysis of variance of data on the effect of different plant regulation treatments on rooting of two year old branch cuttings.

Source of variation	d.f.	S.S.	M.S.	Calculated F value	Tabulated F value	
					5%	1%
Replication	2	0.43	0.21	0.44		
Treatment	19	260.32	13.70	28.54**	1.85	2.41
Error	38	18.23	0.48			

** Significant at 5 per cent level of significance.

APPENDIX X-VI

The pH of soil collected from various localities.

Locality	pH
Bilaspur (From tree base)	8.0
	8.0
	8.0
Gambar (Arki) (From tree base)	8.0
	7.8
	8.0
Khaltoo (Solan) (From nursery beds)	7.5
	8.0
	8.0
Nihari (Bilaspur) (From nursery beds)	8.0
	8.0
	7.8
Sanan (Arki) (From tree base)	8.0
	8.0
	8.0

- Forage plants
- Forests and forestry
- T