DESIGN AND DEVELOPMENT OF A PROTRAY VACUUM SEEDER FOR CROP NURSERY

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B. Tech. (Agril. Engg.)

MASTER OF TECHNOLOGY

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AGRICULTURAL ENGINEERING

(FARM MACHINERY AND POWER ENGINEERING)

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DESIGN AND DEVELOPMENT OF A PROTRAY VACUUM SEEDER FOR CROP NURSERY

By

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B. Tech. (Agril. Engg)

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2018

DECLARATION

I**, DASARI VAISHNAVI**, hereby declare that the thesis entitled "**DESIGN AND DEVELOPMENT OF A PROTRAY VACUUM SEEDER FOR CROP NURSERY**" submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Technology in Agricultural Engineering** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: (**DASARI VAISHNAVI**)

Date: **I.D. No: BEM 16-05**

CERTIFICATE

Ms. **DASARI VAISHNAVI** has satisfactorily prosecuted the course of research and that thesis entitled **“DESIGN AND DEVELOPMENT OF A PROTRAY VACUUM SEEDER FOR CROP NURSERY”** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its thereof has been previously submitted by him/her for a degree of any University.

Date: **Chairperson**

CERTIFICATE

This is to certify that the thesis entitled **"DESIGN AND DEVELOPMENT OF A PROTRAY VACUUM SEEDER FOR CROP NURSERY"** submitted in partial fulfilment of the requirements for the degree of **MASTER OF TECHNOLOGY** in **AGRICULTURAL ENGINEERING with specialization** in **FARM MACHINERY AND POWER ENGINEERING** of the Acharya N.G. Ranga Agricultural University, Bapatla is a record of the bonafide original research work carried out by Miss. **DASARI VAISHNAVI** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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Date : ***(DASARI VAISHNAVI)***

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Abbreviation/Notation	Description
%	Percent
/	Per
±	Plus or minus
°	Degree
Avg	Average
cm	Centimeter
cm^3	Cubic centimetre
d.b.	Dry basis
et al.,	Et cetra
Fig.	Figure
g	Gram
GI	Galvanized iron
h	Hour
hp	Horse power
Hz	Hertz
kg	Kilogram
mm of Hg	Millimetre of mercury column
m	meter
No.	Number
rpm	Revolutions per minute
Rs.	Rupees
s	Second
viz.,	Namely

LIST OF SYMBOLS AND ABBREVIATIONS

ABSTRACT

Name of the Author	:	**DASARI VAISHNAVI**
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Production of good quality seedlings is very much essential for getting high yield and quality crop. Today, direct seeding into plug trays with 50 to 400 cells is the preferred method. Vegetable seeds are small in volume, light in weight and the punching of pricking holes or dibbling operation and sowing in seedling trays are very tedious and repetitive task.

Engineering properties of the seeds like linear dimensions, one thousand seed weight, bulk density and terminal velocity influence the performance of seed singulation mechanism in terms of pickup, singulation and drop of seeds. Hence these properties were determined to design two important components viz., seed tray and seed pickup systems of protray vacuum seeder. Among the seeds used in vegetable nursery the linear dimensions (length, width and thickness), one thousand seed weight and bulk density of vegetable seeds are found for capsicum 4.28±0.03, 3.89±0.02, 0.54±0.01 mm, 8.2±0.07 g, 643.61±7.73 kg m^{-3} respectively. By considering these properties, seed picking units of existing vacuum seeder was modified with hypodermic needles of inner diameter 0.84, 0.69, 0.60 and 0.51 mm and performance study was conducted at a different suction pressure levels viz., 60, 80, 100 and 120 mm of Hg for chilli, brinjal, tomato, capsicum, cabbage, knol-khol and marigold to optimize design and operational

Parameters. It was observed that nozzle orifice size of 0.51 mm at 80 and 60 mm of Hg suction pressure had highest seed singles pickup (%) for all the seeds.

A pipe type vacuum seeder was then designed, developed and experiments were conducted to standardise the location of vacuum inlet viz., inlet at one corner, inlets at diagonal ends, inlet at center on one side and inlets at center on both ends for highest seed pickup efficiency. The experiments were conducted for one selected flat shape seed and for one round shape seed. Four different vacuum inlet locations were made to select best location of inlet such that it gives maximum percent of singles. Performance was evaluated with optimized parameters 0.69, 0.60 and 0.51 mm at single pressure (80 mm of Hg) for flat seed (chilli seed) and round seed (knol-khol). Highest per cent of singles were observed with 0.51 mm orifice size. It was observed that vacuum inlet provided at one corner of pipe had maximum percent of singles as 91.33%, doubles, triples and missings as 2.67% and 96.67% pickup for knol-khol seed. It was also observed that per cent singles, per cent doubles, per cent triples, per cent missings and per cent pickup were 74, 17.33, 5.33 and 6.67 % for chilli seeds respectively. The capacity of protray vacuum seeder was 100 protrays per hour.

Key words: Vegetable nursery, vegetable seeds, protray seeder, nursery mechanization.

Chapter-I

Introduction

Chapter I

INTRODUCTION

India is the second largest producer of vegetables in the world with an estimated annual production of 176.17 million tons from 10.2 million ha in 2016-2017 (*Horticulture Statistics Division 2017*). Production of good quality seedlings is very much essential for getting high yield and quality crop.

Producing plants from seeds is the most important propagation method for agronomic, forestry, vegetable and flowering bedding plants. These methods vary from field seeding operations to very sophisticated greenhouse transplant production systems. In the past, the farmers themselves used to produce the seedlings required for transplanting at a low cost, as most of the vegetable varieties were of open pollinated types. Now-a-days, intensive vegetable cultivation using high yielding F1 hybrids is being taken up by many progressive farmers to augment productivity. As the seeds of hybrids are sold at very high price, converting every individual seed into a healthy seedling becomes essential and this requires intensive nursery management. However, modern greenhouse producers have adopted plug production as the preferred method for transplant production. Seedling production is used extensively to produce flowers and vegetables for outdoor transplanting.

Seeding is the process of sowing seed in a container with a moist growing mix so that they will absorb moisture and germinate. The traditional method of sowing was done by broadcasting the seed over the germination flat or placing the seed in rows. Today, direct seeding into plug trays with 50 to 400 cells is the preferred method. This makes transplanting easier as the seedlings are already singulated and are easier to handle. The cell size is selected based on the size of the seed, the size of the transplant and the length of time the transplant will be grown in the tray. The cell diameter varies from 12.7 to 50.8 mm and depth from 6.35 to 152.4 mm.

1.1 PLUG PRODUCTION

The first crops to be produced in plugs were vegetable transplants in the 1960's by the Florida-based Seedling Corporation. Today, millions of vegetable and flower transplants are produced annually in greenhouses under carefully controlled environmental conditions for optimizing germination and plant growth. This has become possible mainly through the development of the plug system. A plug is a seedling produced in a small volume of medium contained in a small cell, on a single sheet of polystyrene, styrofoam, or other suitable material. Plug flats are filled mechanically with a growing substrate, and seeds are sown mechanically into each cell. Standard plug trays are 550 × 280 mm or 250 × 510 mm, and individual cell sizes may range down to 10 × 10 mm. Cell size dictates the length of time a crop of plugs takes to produce and the time required for the bedding plant grower to finish the crop. Generally, the larger the cell, the longer it takes the plug grower to produce the plug. For the bedding plant grower, the larger the cell (plug), the less time it takes to finish the crop.

Advantages to plug transplants are that the plants are separated into individual root balls, minimizing damage when transplanting. The singulation also allows transplanting to be much faster as the seedlings don't have to be pulled apart. Another advantage is that the plugs can be grown longer before transplanting. This allows greater flexibility in scheduling the transplanting date. However, there is a problem with precision seeding that arises with the fact that the vegetable seeds are small in volume, light in weight and the punching of pricking holes or dibbling operation in seedling trays is very tedious and repetitive task.

1.2 PRECISION MECHANIZED SEEDERS

1.2.1 Needle/Nozzle Seeders

These seeders have nozzles or needles attached to a bar or manifold. Cell trays are indexed one row at a time past dibble and seeding stations. Vacuum nozzles operated by a built in compressor pick up seed from a seed tray and move to discharge it into the cells. A vibrator may keep the seed evenly distributed. Change from one type of seed or tray to another can be done in a few minutes. The size of the nozzle opening determines what size seed can be handled. Nozzles are available from some manufacturers that can handle multiple seeds per cell at one time. Some manufacturers offer a double row seeding. Exhaust air is used to release seed and then clear needle tips. Most models have a conveyor to advance the trays under the seeding head.

1.2.2 Rotating sowing shaft seeder

This seeder is designed for sowing tree seed and uses vibrating trays to singulate the seed. A rotating sowing shaft with cavities sized for the different seed types picks up the seed, rotates and drops it into seed tubes. Multiple seeding is accomplished by rotating as many times as the number of seeds needed per cavity. Seed shafts can be changed in about a minute. The unit can be integrated with a container filling line. The machine is manufactured by BCC AB, Landskrona, Sweden.

1.2.3 Drum and cylinder seeders

This seeder consists of a drum or cylinder with holes sized for the type of seed to be used and spaced for the desired spacing in the plug tray. Seed is picked up from a seed trough by a vacuum on the drum and held until the drum rotates to a position over the plug tray. At this point the seed is ejected by air or water. Some manufacturers use a rotary valve to limit the vacuum to a particular set of holes. Brushes or air curtains are used to remove multiple pickups. An air blast may be employed to clean the holes in the drum. Timing of the drum may be mechanical, infrared beam or electric switches. Drums can be manufactured with a multiple sow set of holes.

Nursery growers have not adopted imported seeders because of high cost, non-availability of sufficient spare parts, repair and maintenance. About eight man hours are required to sow 100 plug trays for raising 9800 seedlings (Gaikwad and Sirohi 2008). This limits the production capacities of most vegetable nurseries due to non-availability of labour. In the peak season, manual labour hardly meets the requirement for raising vegetable seedlings. Mechanization of the seeding operation of plug trays is, therefore, necessary to increase the capacity of the rapidly expanding nursery industry in India.

To enhance the capacities of nurseries and reduce their dependent on manpower during peak periods, there is a need to develop a precision seeder that can accurately sow single seed in plug trays at high seeding rates for different cells. There are very few mechanical seeders for nursery plugs which are suitable for 98 cells, protray of 530 × 250 mm size. In recent past, the farmers are raising vegetable seeds manually in 50 cells as seed growth is good and seedlings are healthier than 98 cells. There is no low cost machine available for raising nursery in 50 cells at present.

Keeping in view the importance of this problem, study is undertaken to design and develop a protray vacuum seeder to utilise seeds effectively and to meet the future need of 50 cells protray seeder with the following specific objectives.

1. To study engineering properties of selected vegetables and ornamental seeds.
2. To design and develop a protray vacuum seeder.
3. To optimize the design and operational parameters of seeder.
4. To evaluate the performance of protray vacuum seeder.

Chapter-II

Review of Literature

Chapter II

REVIEW OF LITERATURE

In view of the objectives of the present investigation, the literatures on the following aspects were reviewed.

i. Determination of physical, mechanical and aerodynamic properties of different seeds.

ii. Design, development and performance evaluation of vacuum seeders.

2.1 PHYSICAL, MECHANICAL AND AERODYNAMIC PROPERTIES OF DIFFERENT SEEDS

Jadhav *et al.* (2017) studied different physical properties like seed size (length and width), shape, thousand seed weight, bulk density and terminal velocity (aerodynamic property) of cabbage (Brassica oleracea) and tomato (Lycopersiconesculentum) seeds at moisture content of 8.24% (w.b.) and 9.71% (w.b.), respectivelyin design of pneumatic seeder for seeding in plug trays. The size of the seeds was measured by analysing with 'Adobe Photoshop CS4' package by acquiring the digital images with a flatbed scanner. The shape of seeds was expressed in terms of roundness by calculating number of pixels covered by digital image of seed area having 300 dpi. The terminal velocity of five randomly selected samples were studied in terminal velocity apparatus (attached with vane probe anemometer) to find the minimum negative pressure to identify vacuum requirement in seed suction tube. The average length and width of seeds were found to be 2.03 ± 0.06, 1.78 ± 0.05 mm and 3.97 ± 0.10, 2.96 ± 0.07 mm for cabbage and tomato, data were used for deciding needle diameter of suction tube. The roundness factor was found to be 0.85 ± 0.03 and 0.64 ± 0.02 for cabbage and tomato seeds, respectively. The thousand seed weights of cabbage and tomato seeds were 3.40 ± 0.05 g and 2.63 ± 0.04 g, respectively. The bulk density of 0.73 g cc^{-1} and terminal velocity of 7.28 ± 0.04 m s^{-1} were observed for cabbage seeds, similarly they were 0.30 g cc^{-1} and 2.67 ± 0.06 m s^{-1} for tomato seeds, respectively. All engineering properties of both types of seeds were found significantly different when compared with each other. The length of both types of seeds had positive correlation with width and negative correlation with height. There was no correlation among other properties. Significant difference was obtained among the properties, while correlation of length of seeds was found with their width and roundness only.

Tang *et al.* (2015) studied the physical properties of some vegetable seeds such as cucumber, eggplant, pepper and tomato (grain diameter ≤7 mm). Physical characteristics (geometrical size, 1000-kernel mass, rest angle, and sliding friction angle) and aerodynamic characteristic (floating speed) of these vegetable seeds were measured. Average geometrical sizes (length, width and thickness) were 9.00, 3.87 and 1.42 mm (cucumber); 3.07, 2.63 and 0.92 mm (eggplant); 3.96, 3.40 and 0.76 mm (pepper) and 3.23, 2.36 and 0.63 mm (tomato). One-thousand kernel mass values were 26.49, 4.27, 5.94 and 2.80 g, respectively. Finally, floating speed rates were 6.38, 5.02, 4.24 and 3.78 m s^{-1}, respectively.

Salawu *et al*. (2014) evaluated design related physical properties of snake tomato seeds found in the South West of Nigeria. The seed length, width, thickness, geometric mean diameter, sphericity, one thousand seed mass, surface area, unit and bulk volume, true and bulk density, specific surface area, porosity, static angle of repose and coefficient of static friction were investigated at 16.56% moisture content dry basis. The results obtained ranged from 12.73-14.65 mm, 7.18-8.36 mm, 4.54-5.59 mm and 7.56-8.55 mm for length, width, thickness and geometric mean diameter, respectively. The unit and bulk volume, true and bulk density were found to be in the range of 24.00-30.00 and 42.00-48.00 cm^3, 0.67-0.80 and 0.42-0.46 g cm^{-3}, respectively. The seed porosity, sphericity and one thousand seed mass were in the range of 36.96-42.86%, 56.41-63.93% and 192.10-202.10 g, respectively. Surface area, specific surface area and static angle of repose investigated were in the range of 1.80-2.30 cm^2, 6.89-8.71 cm^{-1} and 30.96-36.19 degree, respectively. The coefficient of static friction against the surfaces; steel sheet, plywood, rubber and aluminium revealed that they were in the ranges of 0.41-0.52, 0.68-0.81, 0.59-0.75 and 0.47-0.61, respectively. Plywood offered the highest coefficient of static friction while steel sheet gave the least value. The results of this investigation was aimed to provide the necessary data base for design engineers to make its seed planting and the seed extraction mechanized.

Ucer *et al.* (2010) studied effects of moisture content on some physical properties of red pepper (*Capsicum annuum L.*) seed. Physical properties of red pepper seed were evaluated as a function of moisture content. The average length, width and thickness were 4.46, 3.66 and 0.79 mm, respectively, at 7.27% (d.b.) moisture content. In the moisture range of 7.27 to 20.69% (d.b.), studies on rewetted red pepper seed showed that thousand seed mass increased from 7.97 to 8.89 g, the projected area from 8.40 to 9.09 mm^2, the sphericity from 0.525 to 0.555 and the terminal velocity from 4.36

to 4.51 m s^{-1}. The static coefficient of friction of red pepper seed increased linearly against surfaces of four structural materials, namely, rubber (0.394 to 0.477), aluminium (0.255 to 0.382), stainless steel (0.298 to 0.416) and galvanised iron (0.319 to 0.395) as the moisture content increased from 7.27 to 20.69% (d.b.). The bulk density decreased from 402.1 to 360.0 kg m^{-3}, the true density from 795.2 to 746.3 kg m^{-3} and the porosity increased from 49.43 to 51.76%, respectively, with an increase in moisture content from 7.27 to 20.69% d.b.

Ixtaina *et al*. (2008) investigated physical properties of *Salvia hispanica L.* seeds and their application. Physical properties were assessed for white and dark seed separately, except for the angle of repose and static coefficient of friction, which were determined for the seed mixture. The mean moisture content was 7.0% (dry basis). The average for the three characteristic dimensions; length, width and thickness was 2.11, 1.32 and 0.81 mm for dark seeds and 2.15, 1.40 and 0.83 mm for white seeds, respectively. The bulk density, true density and porosity were between 0.667 and 0.722 g cm^{-3}, 0.931 and 1.075 g cm^{-3} and 22.9 and 35.9%, respectively. The equivalent diameter ranged from 1.32 to 1.39 mm. The volume of single grain and sphericity ranged between 1.19 and 1.42 mm^3 and 62.2 and 66.0%, respectively. The geometric mean diameter ranged between 1.31 and 1.36 mm for dark and white chia seeds, respectively. This parameter could be used for the theoretical determination of seed volume and sphericity. One thousand seed mass averaged 1.323 g for dark seeds, and 1.301 g for white seed. The angle of repose varied between 16^o and 18^o whereas the value of static coefficient of friction was 0.28 on galvanized sheet and 0.31 on mild steel sheet.

Coskuner and Karababa (2007) studied physical properties of kernels, grains, and seeds that are necessary for the design of equipment to handle, transport, process and store the crop. The physical properties of coriander seeds were evaluated as a function of seed moisture content, varying from 7.10% to 18.94% (d.b.). In the moisture range, seed length decreased linearly from 4.74 to 4.61 mm, and width, thickness, arithmetic mean diameter, and geometric mean diameter increased linearly from 3.67 to 3.93 mm, 3.39 to 3.54 mm, 3.93 to 4.03 mm and 3.88 to 3.99 mm respectively with increase in moisture content. The sphericity, seed volume and seed surface area increased nonlinearly from 0.820 to 0.867, 24.97 to 28.52 mm^3, and 42.09 to 45.62 mm^2, respectively. One thousand seed weight increased linearly from 8.72 to 9.71 g. The true density increased nonlinearly with moisture content from 332 to 349 kg m^{-3}

while bulk density decreased linearly 234.1 to 220.2 kg m^{-3} in the range of moisture content between 7.10% and 18.94%, d.b. Also, porosity values of coriander seeds increased non-linearly from 33.03% to 35.79%. The highest static coefficient of friction was found on the plywood surface. The static coefficient of friction increased nonlinearly from 0.435 to 0.877, 0.425 to 0.775, 0.379 to 0.839, 0.364 to 0.781, 0.344 to 0.650 and 0.325 to 0.694 for plywood, polypropylene knitted bag, polyvinyl chloride, galvanized iron, cast polypropylene and stainless-steel surfaces, respectively. The angle of repose increased linearly from 24.9° to 30.7° with the increase of moisture content.

Altuntas *et al*. (2005) evaluated some physical properties of fenugreek seeds as a function of moisture content. The average length, width, thickness, geometric mean diameter and unit mass of the seed ranged from 4.01 to 4.19 mm, 2.35 to 2.61 mm, 1.49 to 1.74 mm, 2.40 to 2.66 mm and 0.0157 to 0.0164 g as the moisture content increased from 8.9% to 20.1% (d.b.), respectively. In the moisture content range, studies on rewetted fenugreek seed showed that the sphericity increased from 60.79% to 64.06%, the seed volume from 12.58 to 13.83 mm^3, 1000 seed mass from 15.48 to 16.39 g and surface area from 18.09 to 22.18 mm^2. As the moisture content increased from 8.9% to 20.1% (d.b.), bulk density and kernel density were found to decrease from 701.16 to 645.81 kg m^{-3} and 1240.36 to 1165.25 kg m^{-3}, whereas angle of repose and porosity were found to increase from 14.34° to 16.88° and 43.47% to 44.58%, respectively. The static and dynamic coefficients of friction on various surfaces, namely, plywood, mild steel and galvanized metal also increased linearly with increase in moisture content. The plywood surface offered the maximum friction followed by mild metal and galvanized metal.

Gupta and Das (1997) evaluated physical properties of sunflower seeds and kernels as a function of moisture content. At 6.2% moisture content (d.b.), the average length, width, thickness and unit mass of the seed were 9.52 mm, 5.12 mm, 3.27 mm and 0.049 g respectively. Corresponding values for the kernel were 8.28 mm, 4.09 mm, 2.43 mm and 0.034 g. The mean equivalent diameter and sphericity of the seed were 5.39 mm and 0.57 respectively, while corresponding values for the kernel were 4.32 mm and 0.53. In the moisture range from 4–20% (d.b.), the bulk density of the rewetted seed decreased from 462 to 434 kg m^{-3}, true density increased from 706 to 765 kg m^{-3}, porosity increased from 34.3 to 43.3% and terminal velocity increased from 5.8 to 7.6 m s^{-1}. For the kernel the corresponding values changed from 574 to 628 kg m^{-3}, 1050 to 1250 kg m^{-3}, 45.4 to 50.2 % and 3.5–5.8 m s^{-1}. In the same moisture range the static coefficient of friction varied from 0.40 to 0.58 for seed and from 0.43 to 0.81 for kernel on different surfaces, while the angle of repose varied from 34 to 41^o for seed and 27 to 38^o for kernel.

Jain and Bal (1997) studied three varieties of pearl millet seed, consisting of two hybrids GHB 30 and Bajra 28–15 and one Babapuri (traditional) variety, were graded, dried to 7.4% moisture content (d.b.) and properties of the major fraction were determined. The average three principal dimensions were 3.12, 1.94 and 1.70 mm for GHB 30, 2.98, 1.86 and 1.82 mm for Bajra 28–15 and 3.36, 2.24 and 2.01 for Babapuri varieties. The surface area and volume of single grain were 12.5 mm^2 and 3.8 mm^3 for hybrid varieties and 16.4 mm^2 and 5.8 mm^3 for the traditional variety. Sphericity of the grain for all the varieties was 0.94 and the bulk density and the grain density were 850 and 1600 kg m^{-3} respectively. The shape factor of the grain was 1.07 for GHB 30, 1.01 for Bajra 28–15 and 1.06 for the Babapuri varieties. The porosity of the bulk grain varied between 45 and 49%. The static coefficient of friction was approximately 0.25 on galvanized steel sheet and 0.26 on mild steel sheet. The angle of repose was about 23^o to 25^o.

Singh and Goswami (1996) evaluated physical properties of cumin seed as a function of moisture content. The average length, breadth and thickness were 5.61, 1.77 and 1.55 mm, respectively. In the moisture range from 7 to 22% (d.b.), studies on dried or rewetted cumin seed showed that bulk density initially increased from 477 to 502 kg m^{-3} then decreased from 502 to 410 kg m^{-3}, true density increased from 1047 to 1134 kg m^{-3}, and porosity increased from 54 to 64%. The 1000 seed weight and terminal velocity increased linearly from 4.13 to 4.80 g and 2.6 to 4.8 m s^{-1} respectively. The angle of repose increased linearly from 36.5 to 51.3^o and the static coefficient of friction also increased linearly on four metal surfaces, namely, mild steel (0.54 to 0.70), galvanized iron (0.48 to 0.65), stainless steel (0.37 to 0.62) and aluminium (0.43 to 0.63) with the increase in moisture content from 7 to 22% (d.b.).

2.2 DESIGN AND DEVELOPMENT OF DIFFERENT SEEDERS

Bakhtiari and Ahmad (2017) designed and developed a vacuum seed metering system based on physical and aerodynamic properties of kenaf seeds (*Hibiscus cannabinus L.*). For laboratory tests, a completely randomized design (CRD) was used, data were analyzed by Statistical Analysis Software (SAS) program version 9.1 and means separation test were done by using Duncan’s multiple range test (DMRT). The study results showed that the most suitable opening diameter and opening angle for planting kenaf seeds were 2.5 mm and 120°, respectively, which having the minimum missing and multiple indices with optimum quality of feed index.

Naik and Thakur (2017) designed and analysed an automated seeder for small scale sowing applications for tray plantation method. The saving on seeding cost by using the pneumatic nursery tray seeder was found to be Rs. 20.23 per 1000 seeds sown. This was 66.08% of the manual sowing cost. The payback period of the pneumatic nursery tray seeder was estimated to be 27.87 hours of operation, which was 1.39% of its expected life.

Ekad *et al.* (2016) designed and developed a pneumatically operated automatic seed sowing machine. Theoretical studies on pneumatic equipment for sowing small seeds in cups highlighted the advantages of this type of equipment. Equipment could be used in narrow spaces, being easy to handle and use of driving the vacuum generator could be done electrically. By using this equipment, the productivity increased, the space of establishing the seedlings reduced and the seeds norm diminished. The germination, rise and development space of plants were assured, equipment could be automated and built with minimum costs. Variety of seeds could be easily placed by adjusting the nozzle inlet diameter.

Liu *et al*. (2015) developed and evaluated rice precision seeder for plug seedlings. The device consists of reciprocating driving mechanism, vacuum parts, and vibrating components. The reciprocating driving mechanism connected with the vacuum parts consisted of a crank, a connecting rod and two parallel equal rocker, which generates an appropriate path. The design and virtual simulation results showed that the maximum limit angle of the rocker, the minimum limit angle of the rocker, the swing angle and pickup time were 139.44 A, 68.4 A, 71.04 A and 0.43 s, respectively when the length of crank, connecting rod and rocker were 58 mm, 389 mm and 200 mm, respectively. The reciprocating driving mechanism could satisfy the design requirements of high pickup and low release and presented good dynamic characteristics and force transmission characteristics. The pickup performance was tested. The results showed the rate of picking up one seed was 95%,while the rate of miss-seeding was less than 3% when the vacuum nozzle diameter, pickup vacuum pressure, angular velocity of the crank and the vibrating frequency of the vibrating components were 2.0 mm, 12 kPa ,30 r min^{-1} and 22.5 Hz, respectively. The precision metering device has good sowing performance, meeting the requirements of a rice precision seeding.

Shujuan *et al*. (2014) optimized the parameters of bowl-tray rice precision seeder and improved its performance, three major factors respectively at five levels, including shaped hole diameter, vertical displacement of rice seeds and rotating speed of cam, were tested, the quadratic orthogonal rotational regression experiments were conducted, and the effects on seeding rate, leakage sowing rate and the injury rate were investigated. The test results show that factors affecting rice seeding rate are in the order of shaped hole diameter, rotating speed of cam and vertical displacement of rice seeds. The factors affecting rice planting leakage rate are in the order of shaped hole diameter, vertical displacement of rice seeds and rotating speed of cam, of rice seeds and shaped hole diameter. Optimal parameters (shaped hole diameter: 10 mm, vertical displacement of rice seeds: 27 mm, rotating speed of cam: 13 r min^{-1}) and performance index (seeding rate: 95.43%, leakage sowing rate: 0.37%, injury rate: 0.58%) provided the basis for design and performance improvement of the bowl-tray rice precision seeder.

Sriwongras and Dostal (2014) developed the seeder for sowing tray to reduce the labor cost and the operation time for preparing sowing tray. Papaya seeds were selected for test and sowing tray used has 60 cells per one tray. The dimensions of seeder developed have a width of 1044 mm, a length of 679 mm and a height of 1348 mm. The important components of machine consisted of seed hopper, seed metering device, seed releasing units, soil compressing units and depth controlling units. The seed metering device was established by plastic sheet. The plastic rods cut into keyway along its axis for keeping seeds were inserted into the seed metering device in order to convey the seeds from the seed hopper to the flexible tube. The flexible tubes brought the seeds into seed releasing units located under the part of seed metering device to drop the seeds, 1–2 seeds per cell of sowing tray. The seed metering devices were set 3 units, 1 unit for releasing seeds on 20 cells of sowing tray on the seeder frame. Chain drive mechanism was set to drive the system for releasing seeds on sowing tray. The efficiency test of releasing seed on sowing tray of this seeder was equal to 79%. For operation time of releasing seeds on sowing tray, comparing between this seeder and human hand found that the sowing by the seeder was 7.88 times quicker than the sowing by human hand. In parts of economic analysis of seeder, breakeven point, payback period and benefit cost ratio were considered for economic analysis that were found to be 152,050 trays, 0.03 year and 3.05 respectively. Therefore, the seeder of papaya sowing tray developed was suitable for using in local farmers in Thailand.

Jainping *et al.* (2013) studied development and test of the magnetic precision seeder for plug seedlings. This machine sucked up a seed, which was previously coated with a magnetic powder, by a magnetic head. Number of seeds sucked by the magnetic head as well as the sowing precision was controlled by adjusting the magnetic field. The whole machine which was driven by stepping motors and controlled by a single-chip microcomputer could work automatically. The test results for cabbage, tomato and cucumber seeds showed the rate of single seed sowing was more than 90%, while the rate of miss-seeding was less than 5%. This machine allowed for high sowing precision, good adaptability to various kinds of seeds and a simple structure, as well as automation.

Xiaoyue *et al*. (2013), to meet the requirements of precision seeding, developed a new magnetic plate-type precision seeder and seeding production line based on the magnetic seed-metering principle. The control system was designed based on Programmable Logic Controller (PLC) and Micro Controller Unit (MCU). Automatic programming techniques, sensor technology, acceleration and deceleration control of step motor were integrated into the system. The PLC control system controlled the workflow of the production line to realize accurate positioning of the tray and its coordination. The MCU control system controlled the flip of the sowing board, as well as the up-and-down movement of the seed case for whole tray seed-filling and sowing. Seeding tests for the magnetic powder coated rape seeds showed that the rates of single-seeding, over-seeding and miss-seeding were 90.2778%, 4.6875% and 5.0347% respectively. The seeding speed was up to 14 s per tray. This result met the requirements of precision seeding.

Eok *et al.* (2011) conducted experiment on development of a semi-automatic seeder with vacuum nozzles of quadratic arrangement for small-sized seeds. The prototype consisted of a seeding frame attached with needle nozzle, seed hopper, vibrating device, seeding part, vacuum ejector, seed tube, etc. Needle diameter according to the kinds of seed was different, the needle diameter for salvia and lettuce seed was suitable for 0.34 mm needle nozzle and 0.4 mm taper nozzle. Seeding rate of the seeder was 92% and more at 0.34 mm diameter needle nozzle and 0.4 mm taper nozzle. Weight and the eccentricity of the eccentric weight affects the seed hopper vibration. Eccentric weight suitable for seed hopper vibration was 11 g and eccentric distance was 0.5 mm. Vibration acceleration of upward direction was 0.363 m s^{-2}. Working capacity of the seeder was 160 trays per hour.

Gaikwad and Sirohi (2008) designed a low-cost pneumatic seeder for nursery plug trays using indigenous materials and off-the-shelf available standard components.

Seeder could make indents in one row of cells in a plug tray and simultaneously place single seed in the indented cells. Seeder worked satisfactorily at suction pressures of 4.91 and 3.92 kPa and nozzle diameters of 0.46 and 0.49 mm to achieve more than 90% single seed sowing in the case of capsicum and tomato, respectively. Capacity of seeder ranged between 38000 and 60000 cells h^{-1}. Total cost of sowing 1000 cells using a prototype precision plug seeder was found to be Rs. 1.56 (US$0.034) which was only 15.27% of the estimated cost of manual sowing.

Min *et al.* (2008) investigated vibration conditions of the seed hopper and eccentric weight, and to optimize the seed-pickup performance of each nozzle by suction pressure. As shown in the experiments, the fluctuations of the jumping height of the seeds were at amplitude of 0.4 mm and frequency heights of the seeds were increased as the air pressure increased and the eccentric weight decreased, regardless of hopper. The best seeding rate of the seed hopper was 98% at the 300-seed cell, when the condition of the air pressure was 94.6 kPa-abs., amplitude and frequency of the seed hopper vibration were at 0.57 mm and optimum vibrating conditions of the seed hopper were decided into frequency 43.6-43.8 Hz.

Gaikwad *et al*. (2007) determined optimum combination of suction pressure and nozzle size for the singulated picking of tomato and capsicum seeds. Sixteen combinations of different nozzle sizes and suction pressures were evaluated for singulation and seeding of these seeds in plugtrays. The suction pressure was found to influence the picking of single seed, the most followed by nozzle size for both, capsicum and tomato seeds. The optimum combination of suction pressure and nozzle hole size for more than 90% singles in the case of capsicum was 500 mm of water column (4.91 kPa) and 0.49 mm and for tomato it was 400 mm of water column (3.92 kPa) and 0.46 mm, respectively.

Rathinakumari *et al.* (2005) designed and developed tray type vacuum seeder and tray type dibbler for vegetable nursery. Tray type vacuum seeder was made of acrylic sheet and it consisted of a vacuum chamber, seed plate with 98 holes to pick the seeds, vacuum pump and necessary control valves. Seeder picked and dropped the round shaped seeds like cabbage, cauliflower and knoll khol perfectly, i.e., 100% singles. For other vegetable seeds, the metering performance of the seeder was good with singles in the range of 93-97%, doubles between 3-7% and no missing were recorded. It was suggested that these handy and low-cost tray type dibbler and tray type vacuum seeder was very much useful for small vegetable nursery growers.

Karayel *et al.* (2004) determined the optimum vacuum pressure of a precision vacuum seeder and developed mathematical models by using some physical properties of seeds such as one thousand kernel mass, projected area, sphericity and kernel density. Maize, cotton, soya bean, watermelon, melon, cucumber, sugarbeet and onion seeds were used in laboratory tests. One thousand kernel mass, projected area, sphericity and kernel density of seeds varied from 4.3 to 372.5 g, 5-77 mm^2, 38.4-85.8% and 440-1310 kg m^{-3}, respectively. The optimum vacuum pressure was determined as 4.0 kPa for maize I and II; 3.0 kPa for cotton, soya bean and watermelon I; 2.5 kPa for watermelon II, melon and cucumber; 2.0 kPa for sugarbeet and 1.5 kPa for onion seeds. The vacuum pressure was predicted by mathematical models. According to the results, the final model could satisfactorily describe the vacuum pressure of the precision vacuum seeder with a chi-square of 2.51×10^{-3}, root mean square error of 2.74×10^{-2} and modelling effciency of 0.99.

Kim *et al.* (2003) studied on vacuum nozzle seeder for cucurbitaceous seeds and developed a vacuum nozzle seeder for the automation of large seeds sowing of fruits, vegetables and rootstocks. Moreover, the seeding efficiency was examined to find the optimum operating condition considering high precision seeding. Important operating factors for high seeding rate were typically nozzle diameter and absorbing vacuum pressure. Optimum nozzle diameters were found to be 1.5, 1.5 and 2.0 mm for chambak, tuktozwa and hukjong while the optimum vacuum pressures were 8.0, 1.06 and 5.3 kPa, respectively.

Zigmanov *et al*. (1997) studied efficiency of machine sowing of vegetable seeds into containers. The seeding of vegetable crops into polystyrene containers by means of pneumatic sowing table was studied. Eighteen vegetable crops were included in the study. Pneumatic sowing table IMT-FOP 634-850 was used. On the basis of the results it was concluded that the following factors affected the efficiency of sowing: degree of vacuum, nozzle diameter, method of diving the nozzles into the vessel with seed, shape of seed as well as the rate of finishing of seed (cleanliness, sizing, surface polishing, prilling). The highest efficiency of sowing was performed by using seed of rounded shape, smooth surface (Brassicas family and prilled seed of different vegetable crops). On the basis of the coefficient of pneumatic sowing introduced, by means of the appropriate regression equations it was possible to select the operation regime of sowing table in advance, which gave the best results for certain kind of prilled seed.

Guarella *et al*. (1996) conducted experimental and theoretical performance of a vacuum seeder nozzle for vegetable seeds. The performance of a vacuum seeder depends on several variables that interact in a complex way. The maximum distance at which seeds may be picked up from the nozzle, depends on the dimensions of the nozzle, on the depression applied at the nozzle and on the shape and dimensions of the seeds themselves. A mathematical model was devised based on the general principles of fluid dynamics and valid for seeds with a round shape, to identify the major parameters regulating the phenomenon. Experimental tests with a vacuum pick-up device were carried out to measure the maximum distance at which pick-up took place when the depression was varied in the interval from zero to 80 kPa. The tests were carried out for four different types of seeds and seven different nozzles. For all nozzles and seeds tested, it was found that depressions in excess of 20 kPa did not substantially increase the pick-up distance.

Sial and Persson (1984) evaluated seven vacuum nozzles in a stationary device similar to horticultural seed flat seeders to learn correct seed orientation, air pressure for pickup, holding and transport, brush-off method and seed ejection. Theoretical derivations and experiments showed that the pressure difference needed for pickup of a seed increased with the fourth power of the pickup height for heights of more than one seed radius. An exponential relationship was found to apply closer to the nozzle. Recommendations for a suitable pneumatic metering device for nearly spherical seeds were made with regard to nozzle type, seed lift height, seed orientation, brush-off device and seed ejection.

Walters (1981) reported that nurserymen could grow better stock using Hawaiian forestation system in which tree and shrub seedlings were grown in dibbling tubes (about 5 inches deep and 11/8 inches in diameter at the bottom), which were filled with a mixture of sphagnum peat and vermiculite and transported in racks each holding 100 seedlings. A vacuum seeder was used to sow flat seeds while round seeds were sown by manual seeder by which multiple sowings could be made. After placement, the seeds were recovered with a 5 mm thick layer of crushed basalt. It was reported that eight persons could process about 1,00,000 tubes per day, and one person could plant 750-1000 seedlings per day in the nursery. Guava, passion fruit, and pawpaw seedlings were reported to be grown successfully by this method.

Chapter-III

Material& Methods

Chapter III

MATERIAL AND METHODS

The present research study was undertaken in the Section of Agricultural Engineering, ICAR-Indian Institute of Horticultural Research, Hessaraghatta, and Bengaluru and in the laboratories of College of Agricultural Engineering, Bapatla. Materials used and methods adopted to i) determine engineering properties of selected vegetable seeds ii) design and develop components of protray vacuum seeder iii) optimize design and operational parameters of seeder iv) evaluate performance of protray vacuum seeder, are presented in the following section.

3.1 RAW MATERIALS

Good quality seeds (chilli, capsicum, tomato, brinjal, cabbage, knol-khol and marigold) (Plate 3.1) were procured from local market in Bengaluru for conducting experiments.

3.2 MOISTURE CONTENT

The moisture content of seeds were determined by oven drying method. Samples were kept in oven at 130˚ for 2 hours. Before weighing, dried samples were cooled in decicator. Moisture content was calculated by following formula in dry basis:

$$\text{Moisture content (d.b \%)} = \frac{\text{Initial weight of sample (g) - Dried weight of sample (g)}}{\text{Dried weight of sample (g)}}$$

3.3 DETERMINATION OF ENGINEERING PROPERTIES OF VEGETABLE AND ORNAMENTAL SEEDS

3.3.1 Physical properties

3.3.1.1 Linear dimensions

One hundred seeds were randomly selected from each type of seed and their three dimensions namely, length (l), width (b) and thickness (t) for flat seeds and major, minor diameters for round seeds were measured using electronic microscope assisted with Q-capture software (Plate 3.2).

3.3.1.2 Geometric Mean Diameter

Geometric mean diameter of seeds were calculated by using following equation (Mohsenin, 1970).

$$D = (l \times b \times t)^{1/3}$$

Plate. 3.1 Vegetable seeds used in the study

Plate. 3.2 Determination of linear dimensions by using Q-capture method

3.3.1.3 Sphericity

Sphericity (S) of seeds were determined by formula (Mohsenin, 1970).

$$S = \frac{(lbt)^{1/3}}{l}$$

3.3.1.4 One thousand seed weight

One thousand seeds were randomly selected and weighed using an electronic balance. This procedure was repeated for five times.

3.3.1.5 Bulk density

The samples were filled into 50×50×50 mm square container and 90 mm diameter, 50 mm height cylinder up to the top level. Then the samples in the container were weighed by using an electronic balance (Mohsenin 1970). The bulk density was calculated by using following formula.

$$\text{Bulk density (kg/m}^3) = \frac{\text{Weight of the sample in container (kg)}}{\text{Volume of container (m}^3)}$$

3.3.1.6 Terminal velocity

Terminal velocity was measured by using wind tunnel apparatus. For each experiment, a sample was dropped into the air stream from the top of the air column, up from which air was blown to suspend the material in the air stream. The air velocity near the location of the seed suspension was measured by anemometer at the inlet side. The procedure was repeated for five times.

3.4 SIZE OF PROTRAY USED IN THE STUDY

The size of the pro-trays commercially used by the vegetable nursery growers was 535 × 280 × 45 (L×W×H) mm (Plate 3.3). Pro tray of 50 cells in total has 10 cells along the length and 5 cells along the width. The centre to centre distance between two cells was 52 mm. Each cell has top diameter of 45 mm, bottom diameter of 33 mm and depth of 50 mm which were made of non-rigid plastic.

3.5 ICAR-IIHR VACUUM SEEDER

The ICAR-IIHR vacuum seeder consisted of i) main frame, ii) dibbler, iii) vacuum seeder, iv) seed tray, v) protray holder and vi) vacuum pump

3.5.1 Main frame

The overall main frame of the machine (Fig. 3.1) was fabricated out of M.S. angle section of 40×40×5 mm and had dimension of 1064×830×635 mm. A wooden platform of 660×335 mm was made to place pro-tray for operation. A movable protray holder (Fig. 3.4) was fabricated out of and had dimension of 560×315 mm to hold vacuum chamber and this enabled conveying seeder to dibble protray. Dibbler, vacuum pump, seeder and seed tray were fitted to the main frame. Four number of swivel type caster wheels of 150 mm diameter × 50 mm thickness were provided for easy mobility of machine.

3.5.2 Dibbler

Rolling type dibbler (Fig. 3.3) of 115 mm diameter and 600 mm in length consists of fifty nylon pegs each of 25 mm diameter and 25 mm long were fitted in such a way to match the center of the peg to the center of cavity in protray.

3.5.3 Vacuum chamber

A vacuum chamber of size 550×305×40 mm (Fig. 3.6) was fabricated out of acrylic sheet. Fifty holes of 39 mm were drilled and fitted with different metal nozzles. The complete assembly was made of air tight. In order to give required support to bottom sheet against vacuum pressure, six numbers of acrylic pillars were mounted inside the chamber. Two pneumatic fittings with control valves were fitted, one on each side of the chamber. One valve was connected to a vacuum pump and other valve was opened to the atmospheric pressure to enable the seeds to detach from the nozzle orifices.

3.5.4 Seed tray

Seed tray (Fig. 3.5) was fabricated out of nylon board of 540×293×25 mm. As per center to center distance between each cell in protray, fifty grooves of 15 mm diameter and 15 mm depth was made to fill the seed.

3.5.5 Vacuum pump

Vacuum seeder unit was connected to an oil lubricated vacuum pump of three phase 1400 rpm, 1 HP. The maximum capacity of vacuum pump was 20 m^3 with minimum 0.5 mbar pressure.

3.6 MODIFICATION OF VACUUM SEEDER

3.6.1 Seed picking units

Hypodermic needles which were commercially available in wide range of gauge sizes and low cost were used as seed picking units. Orifice sizes having inner diameter of 0.84, 0.69, 0.60, 0.51, 0.41, 0.34 and 0.31 were selected for preliminary studies based on linear dimensions of seed (plate 3.4). The length of needles were kept as 38 mm so that they could reach the seed holder for picking seeds and for this, needles were first cut down to 38 mm, then opening of needle by pressing. From preliminary studies among all the orifice sizes only 0.84, 0.69, 0.60 and 0.51 mm orifice sizes showed better performance. Hence, these 4 needles were used for further experiment.

Table 3.1 Specifications of hypodermic needles

S.No	Gauge	Colour	Inner diameter (ID) (mm)	Outer diameter (OD) (mm)	Thickness (mm)
1	18	Pink	0.84	1.27	0.216
2	19	Light yellow	0.69	1.07	0.191
3	20	Yellow	0.60	0.99	0.153
4	21	Green	0.51	0.82	0.153
5	22	Ash	0.41	0.72	0.153
6	23	Blue	0.34	0.64	0.153
7	24	Violet	0.31	0.57	0.127

3.6.2 Modified vacuum chamber

A vacuum chamber of size of 550×305×40 mm was fabricated using acrylic sheet. Bottom sheet was drilled such that it was fitted with nylon tubes to hold needles. The complete assembly was made of air tight. In order to give required support to bottom sheet against vacuum pressure, six numbers of acrylic pillars were mounted inside the chamber. Two inlets were provided at both sides of chamber.

3.6.3 Working of the vacuum seeder

The working principle of vacuum seeder was vacuum created by suction unit. A sufficient amount of seed was placed in the seed tray. Before starting to work with vacuum seeder, a vacuum pressure of predetermined level was created by adjusting pressure with pressure regulating system. Protray filled with media was first placed on the platform below the dibbling unit, platform was then pushed and pulled so that dibbler made uniform indents in all fifty cells. Vacuum chamber along needles which was on a platform above seed tray picked the seed when valve was opened. Then the vacuum chamber was made to move on platform to the pro-tray. Cutting off the valve will allow the seed to drop in the center of the cell in the pro-tray.

Plate. 3.3 Pro-tray (50 cells)

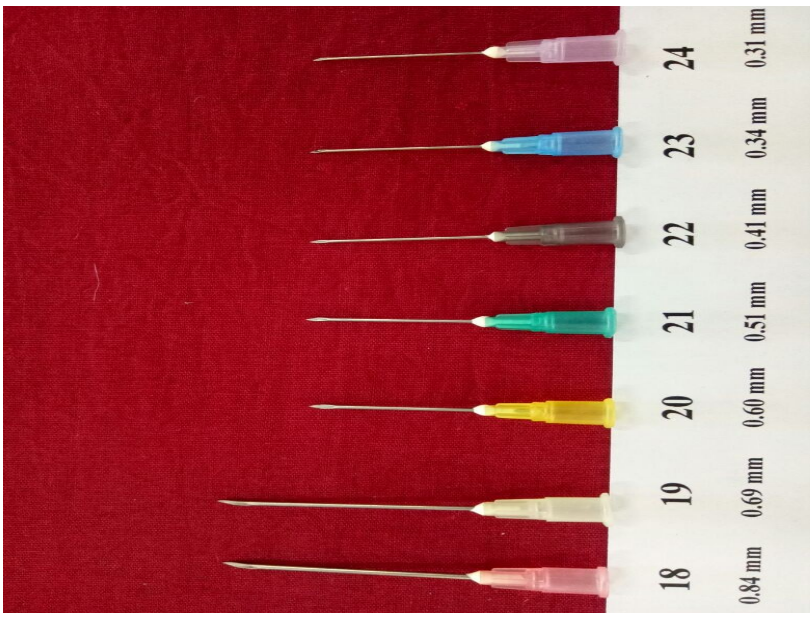


Plate. 3.4 Seed picking units (hypodermic needles)

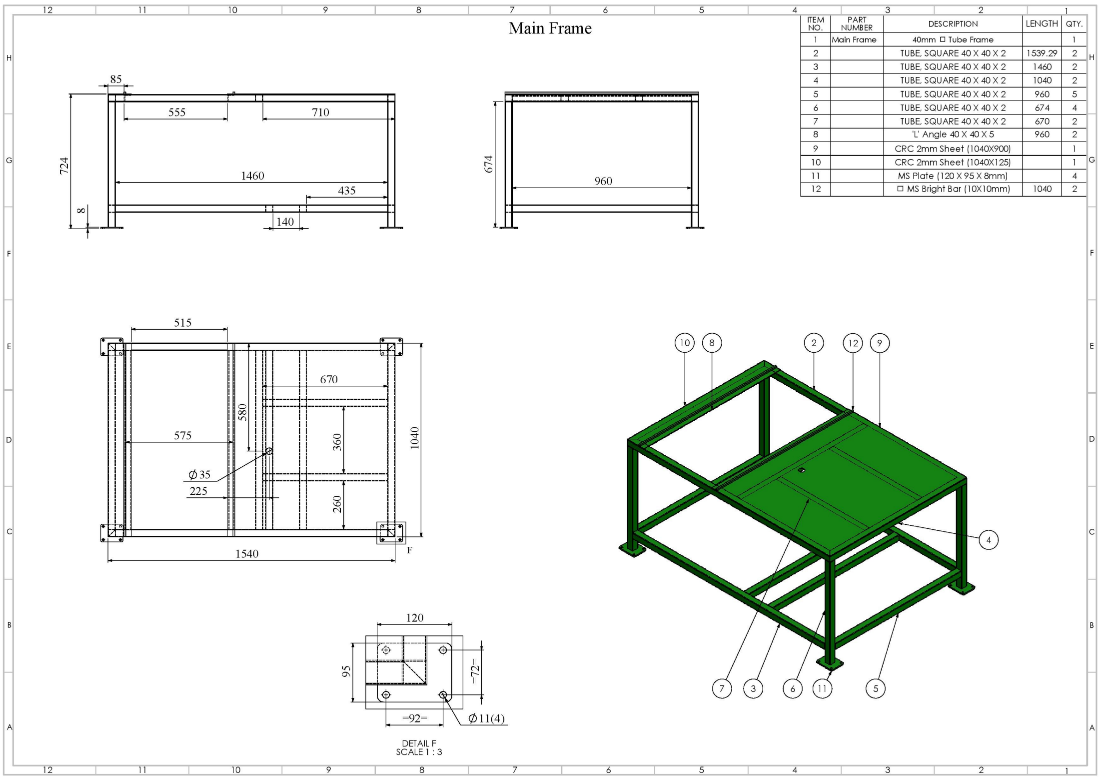


Fig. 3.1 Main frame 1 of the vacuum seeder

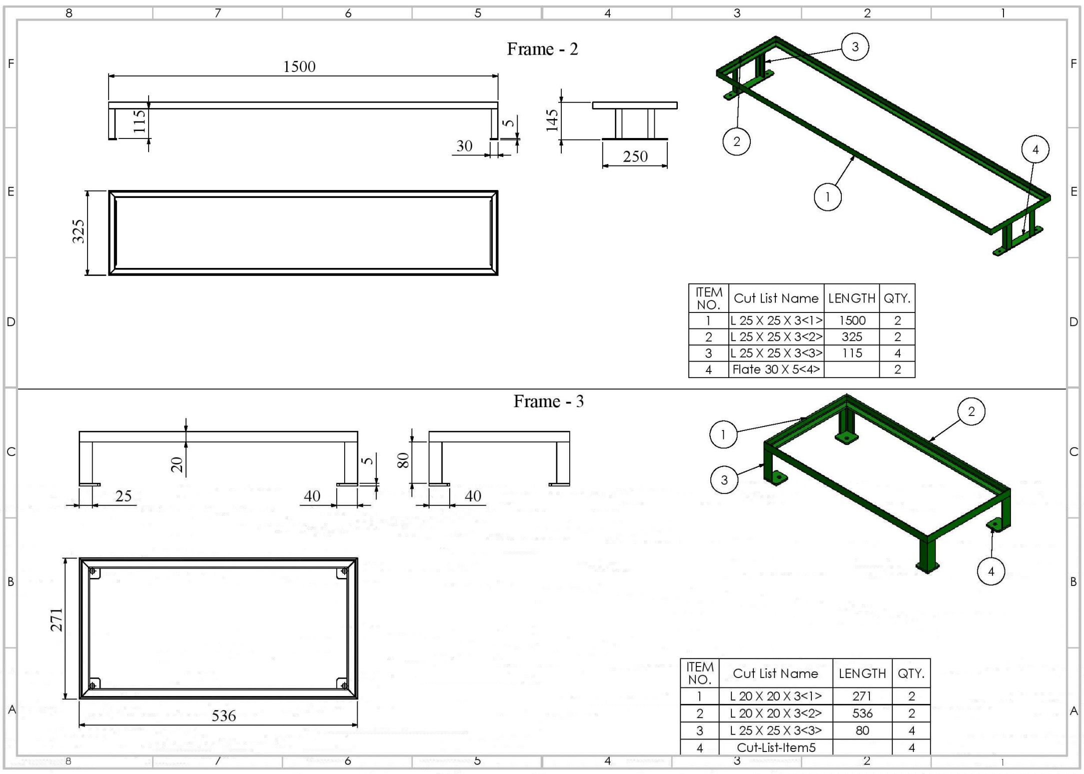
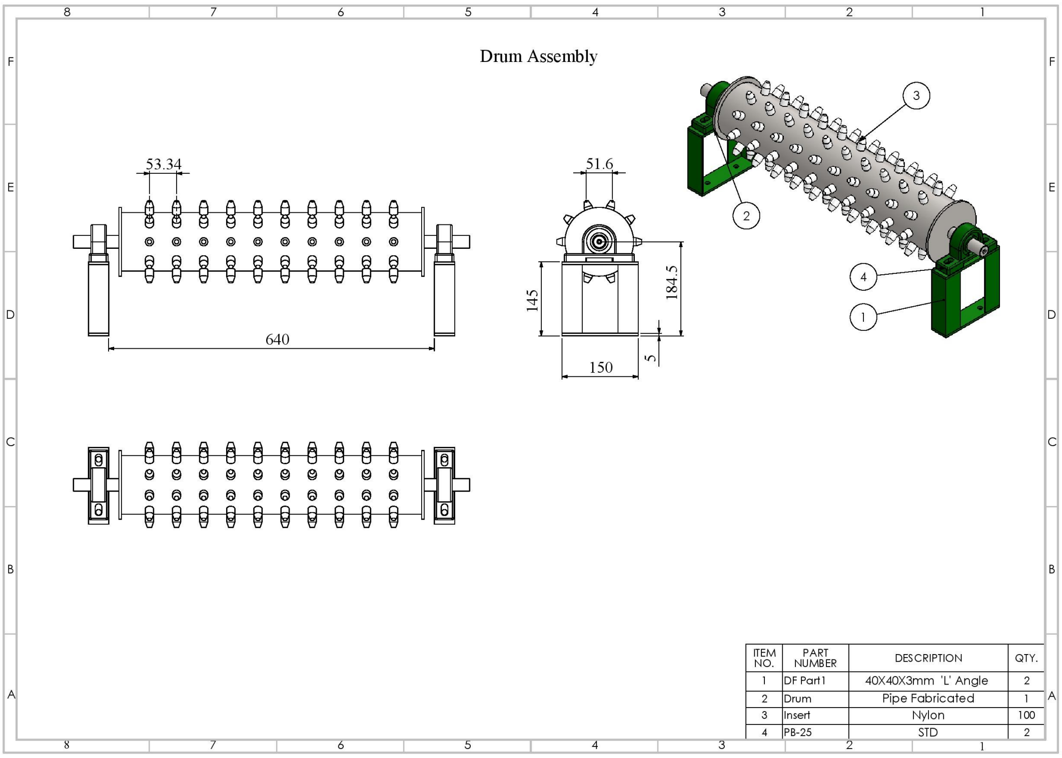
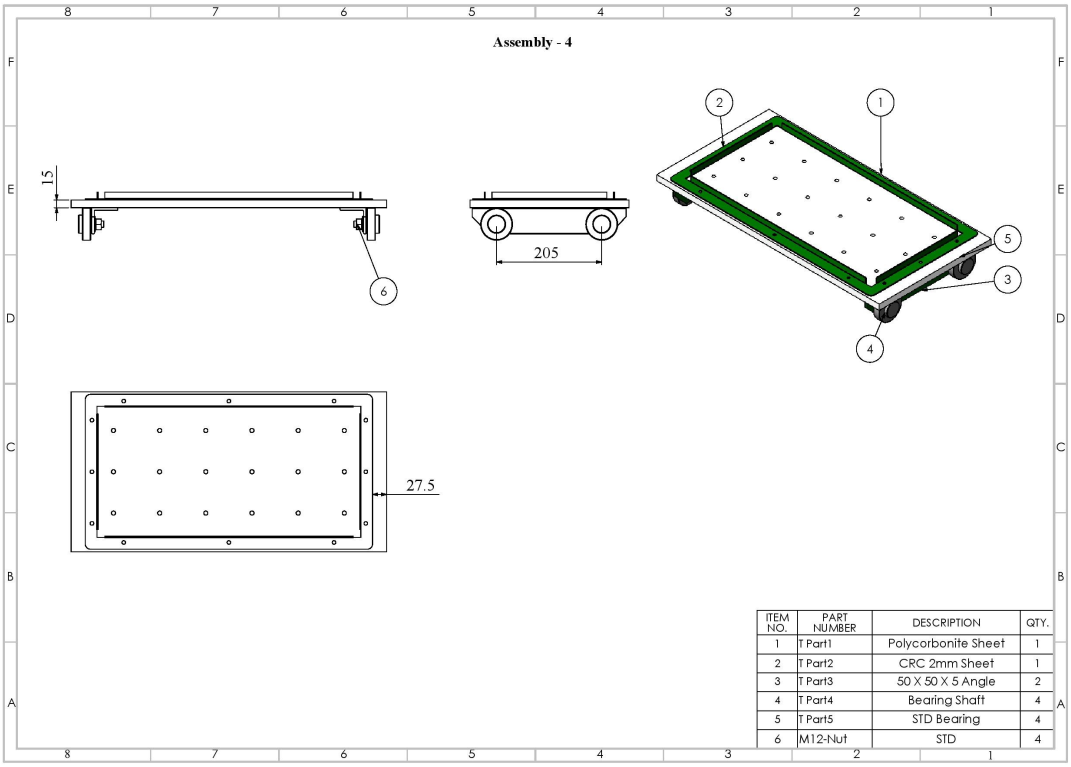


Fig. 3.2 Frame 2 of the vacuum seeder



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	DF Part1	40X40X3mm 'L' Angle	2
2	Drum	Pipe Fabricated	1
3	Insert	Nylon	100
4	PB-25	STD	2

Fig. 3.3 Drum assembly of the vacuum seeder



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	T Part1	Polycorbonite Sheet	1
2	T Part2	CRC 2mm Sheet	1
3	T Part3	50 X 50 X 5 Angle	2
4	T Part4	Bearing Shaft	4
5	T Part5	STD Bearing	4
6	M12-Nut	STD	4

Fig. 3.4 Movable trolley of the vacuum seeder

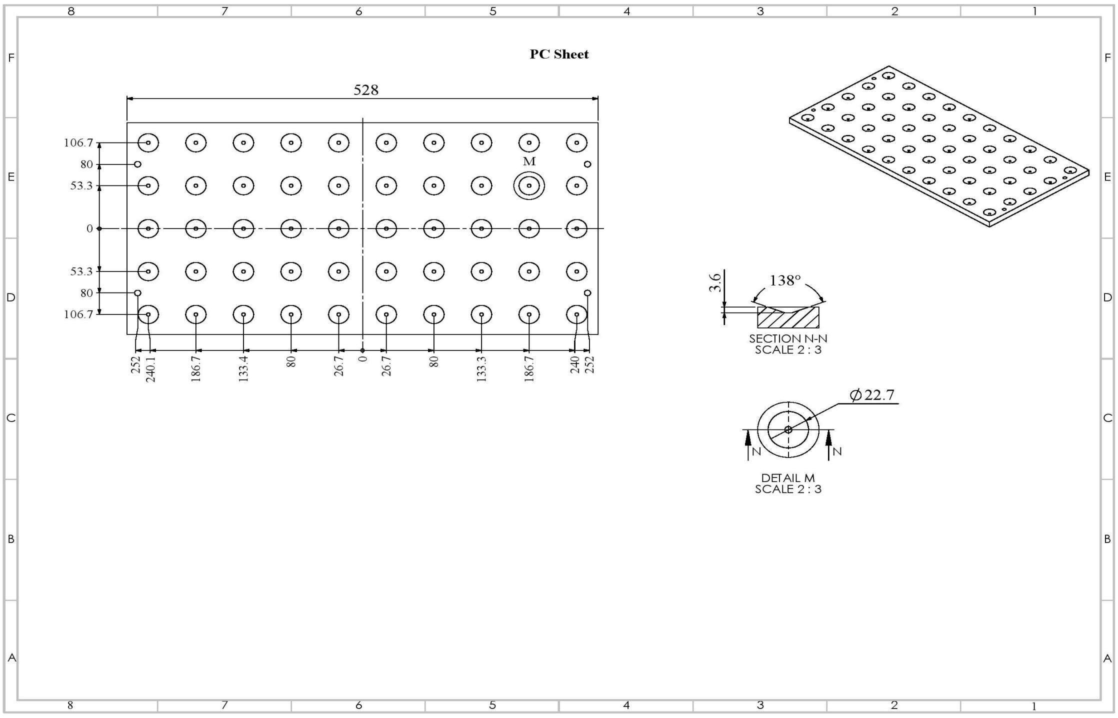
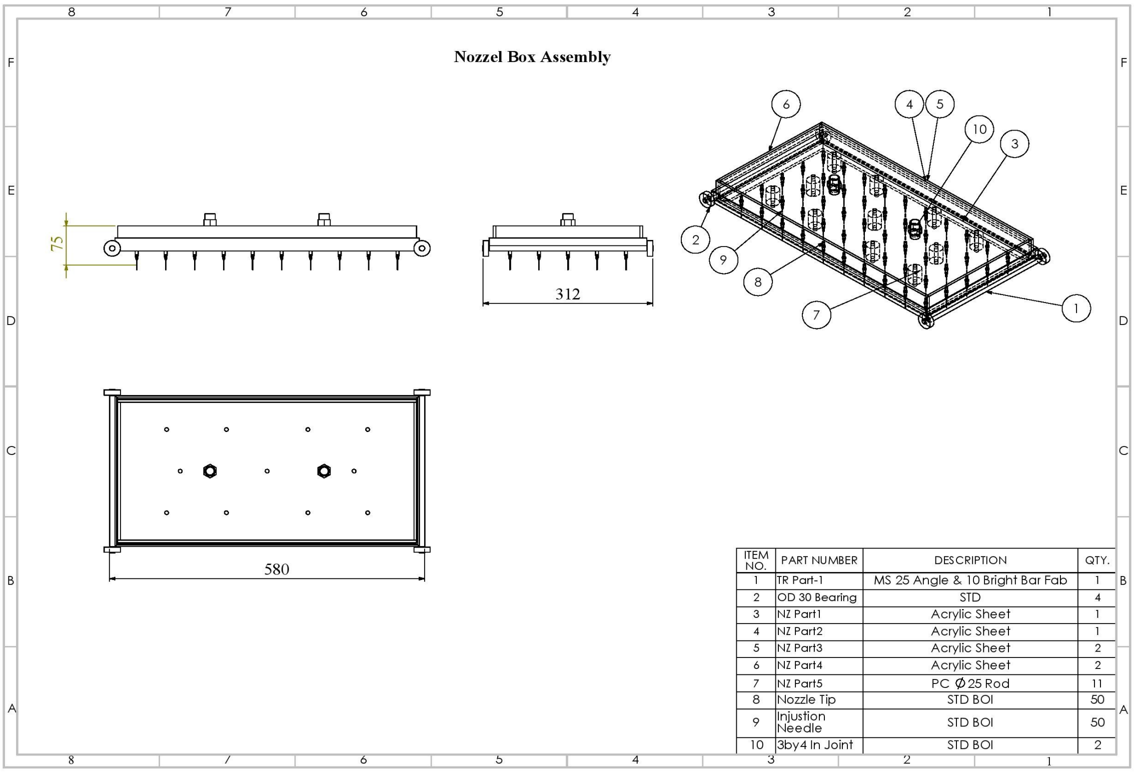
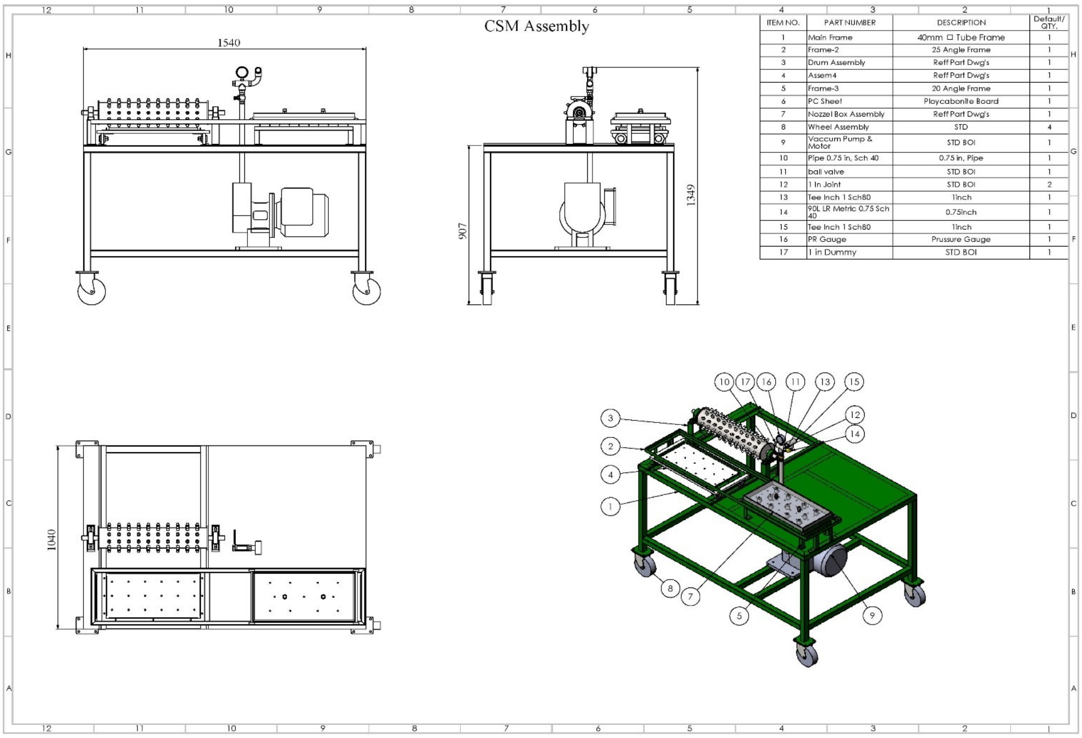


Fig. 3.5 Seed tray of 50 cavities



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TR Part-1	MS 25 Angle & 10 Bright Bar Fab	1
2	OD 30 Bearing	STD	4
3	NZ Part1	Acrylic Sheet	1
4	NZ Part2	Acrylic Sheet	1
5	NZ Part3	Acrylic Sheet	2
6	NZ Part4	Acrylic Sheet	2
7	NZ Part5	PC Ø25 Rod	11
8	Nozzle Tip	STD BOI	50
9	Injustion Needle	STD BOI	50
10	3by4 In Joint	STD BOI	2

Fig. 3.6 Nozzle box assembly



ITEM NO.	PART NUMBER	DESCRIPTION	Default/ QTY.
1	Main Frame	40mm ☐ Tube Frame	1
2	Frame-2	25 Angle Frame	1
3	Drum Assembly	Reff Part Dwg's	1
4	Assem4	Reff Part Dwg's	1
5	Frame-3	20 Angle Frame	1
6	PC Sheet	Ploycabonite Board	1
7	Nozzel Box Assembly	Reff Part Dwg's	1
8	Wheel Assembly	STD	4
9	Vaccum Pump & Motor	STD BOI	1
10	Pipe 0.75 in, Sch 40	0.75 in, Pipe	1
11	ball valve	STD BOI	1
12	1 In Joint	STD BOI	2
13	Tee Inch 1 Sch80	1inch	1
14	90L LR Metric 0.75 Sch 40	0.75inch	1
15	Tee Inch 1 Sch80	1inch	1
16	PR Gauge	Prussure Gauge	1
17	1 in Dummy	STD BOI	1

3.7 OPTIMIZATION OF DESIGN AND OPERATIONAL PARAMETERS OF MODIFIED VACUUM SEEDER

Experiments were conducted to optimize the following design and operational parameters of vacuum seeder.

3.7.1 Design parameters

After conducting preliminary studies 4 different hypodermic needles were selected as seed picking units having orifice inner diameter of viz., i) 0.84 mm, ii) 0.69 mm, iii) 0.60 mm and iv) 0.51 mm.

3.7.2 Operational parameters

Experiments were conducted to optimize the vacuum pressure such that it should have highest singulation efficiency.

1. 120 mm of Hg
2. 100 mm of Hg
3. 80 mm of Hg
4. 60 mm of Hg

3.7.3 Independent parameters

Six types of seeds viz., chilli, brinjal, tomato, capsicum, knol-khol and marigold were used for studies.

The combinations of various treatments are given below.

Table 3.2 Treatment of experiments for modified vacuum seeder

Orifice diameter	Suction pressure (mm of Hg)	Number of replications(R)
0.84 mm (N1)	120 – P1	
	100 – P2	
	80 – P3	
	60 – P4	
	120 – P1	
	100 – P2	
	80 – P3	

0.69 mm (N2)	60 – P4	3
0.60 mm (N3)	120 – P1	
	100 – P2	
	80 – P3	
	60 – P4	
0.51 mm (N4)	120 – P1	
	100 – P2	
	80 – P3	
	60 – P4	

3.7 PERFORMANCE EVALUATION OF SEEDER

The following performance parameters were observed during testing:

a) Number of singles

b) Number of doubles

c) Number of triples

d) Number of missings

e) Total pickup

From data the following parameters were determined

3.7.1Percentage of singles

Percentage of singles was calculated by using the following formula

$$\text{Percentage of singles (\%)} = \frac{\text{Number of cells having single seed}}{\text{Total number of cells}} \times 100$$

3.7.2 Percentage of doubles

Percentage of doubles was calculated by using the following formula

$$\text{Percentage of doubles (\%)} = \frac{\text{Number of cells having doubles}}{\text{Total number of cells}} \times 100$$

3.7.3Percentage of triples

Percentage of triples was calculated by using the following formula

$$\text{Percentage of triples (\%)} = \frac{\text{Number of cells having triples}}{\text{Total number of cells}} \times 100$$

3.7.4 Percentage of missings

Percentage of triples was calculated by using the following formula

$$\text{Percentage of missings (\%)} = \frac{\text{Number of empty cells}}{\text{Total number of cells}} \times 100$$

3.7.5 Percentage of total pickup

Percentage of total pickup was calculated by using the following formula

$$\text{Percentage of triples (\%)} = \frac{\text{Number of cells having singles, doubles and triples}}{\text{Total number of cells}} \times 100$$

3.8 STATISTICAL ANALYSIS

The results of the machine performance for different treatments of vacuum seeder were analyzed using Factorial Completely Randomized Design with 3 replications by using online based OPSTAT software. The mean of the observation was subjected to two-way ANOVA.

3.9 DRAWBACKS OF MODIFIED VACUUM SEEDER

1. Seed tray had to be lifted for every tray to pick seed which was time consuming and difficult operation.

2. Non-uniform distribution of pressure.

3.10 DESIGN AND DEVELOPMENT OF PIPE TYPE VACUUM SEEDER

3.10.1. Determination of minimum air velocity at needle

Minimum nozzle air velocity required through the nozzle orifice to pickup one seed at a time, by using following equation (Short and Huber, 1970):

$$V_n = \frac{1}{r}\sqrt{\frac{2Wg^2}{\pi \times \gamma_a \times g}}$$

Where,

V_n– Average air velocity through nozzle orifice, m/sec

W – Seed weight, kg

g – Gravitational constant, 9.81 m/sec^2

r – Radius of nozzle orifice, m

γ_a– Air specific weight, kg/m^2-sec^2

Maximum seed weight is for capsicum 1000 seed weight = 8.201× 10^{-6}kg

Radius of nozzle orifice, r = 18 gauge = 0.84 mm

γ_a = 1.2 kg/m^3

Then,

$$V_n = \frac{1000}{0.042}\sqrt{\frac{2\times 0.00821\times 9.81\times 9.81}{\pi\times 1.2\times 9.81\times 1000}}$$

V_n= 15.49 m/s

3.10.2 Flow rate through one needle

$$Q = a\ v$$

$$Q = \frac{\pi}{4}\,(0.084)^2\,(1549.28)$$

$$Q = 8.58\ cm^3/s$$

Flow rate through 50 needles = 8.58 × 50

= 429 cm^3/s = 0.429 lit/s

With 20% freeboard, total flow rate is 514.8 cm^3/s = 0.515 lit/s

3.10.3 Diameter of pipe to be designed

As per protray dimensions,

Length of each pipe = 530 mm

Width of each pipe = 275 mm

$$Q = A\ L$$

$$514.8 = \frac{\pi}{4} d^2 \times 3500$$

$$d = 13.6 \text{ mm}$$

Diameter of pipe required = 13.6 mm

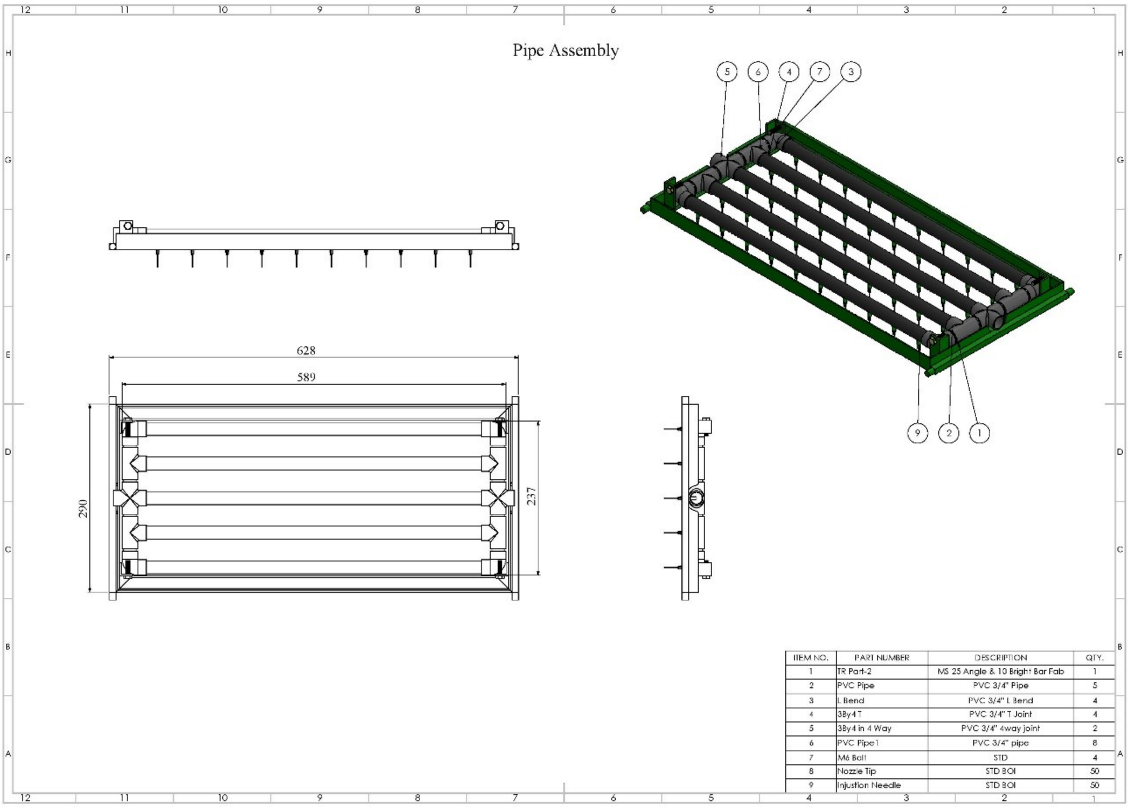


Fig. 3.8 Pipe assembly of modified vacuum seeder

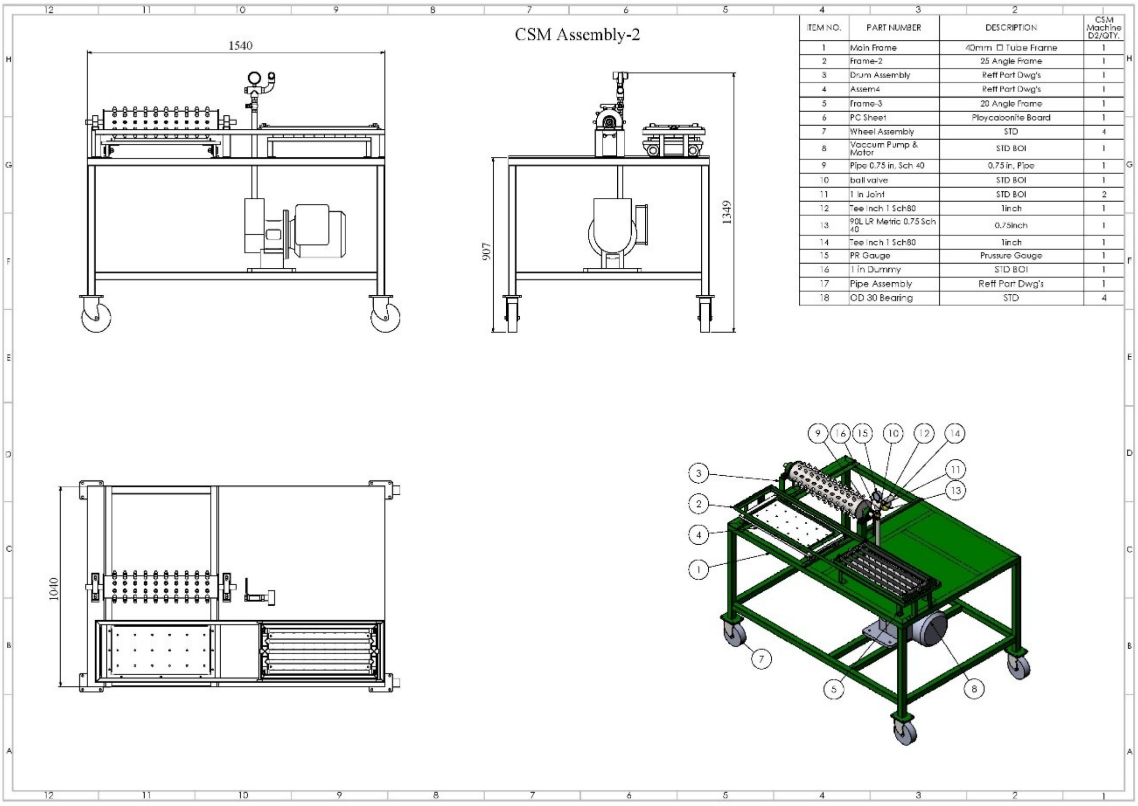


Fig. 3.9 Modified vacuum seeder

3.10.4 Development of vacuum seeder

The following factors were considered while developing the vacuum seeder.

1. Suitability of machine to different seeds

2. Picking only one seed for each needle

3. No damage to seed

4. Should be women friendly

3.10.5 Pipe typevacuum seeder

Five pipes of 15 mm diameter and length of 512 mm were selected (Fig. 3.8). On each pipe, 10 holes were drilled of 3.9 mm diameter according to two cells center to center distance of 50 cell pro tray. These holes were fitted with nylon tubes of 15 mm length inorder to fit needles. Pipes were then fixed to T-joints at each ends and end caps were provided at the corners so that vacuum can circulate continuously. Hypodermic needles of 0.69, 0.6 and 0.51 mm were reduced to 38 mm and fixed to the nylon tubes. Inlet was provided with one-fitting brass elbow.

3.10.6 Selection of best location of vacuum inlet

The four different vacuum inlet locations were selected plate 3.5 (a)-(d) viz.,

1. Location 1- Inlet at one corner
2. Location 2- Inlet at diagonal ends
3. Location 3- Inlet at center on one side
4. Location 4- Inlets at center on both ends

Seeder was tested for performance using two seeds like chilli and knol-khol. The selected systems were tested with 3 hypodermic needles (like 19, 20 and 21 gauge) to select best location of inlet.

Plate. 3.5 (a) Location 1- Inlet at one corner

Plate. 3.5 (b) Location 2- Inlet at diagonal ends

Plate. 3.5 (c) Location 3- Inlet at center on one side

Plate. 3.5 (d) Location 4- Inlets at center on both ends

The combinations of various treatments are given below:

Table. 3.3 Design of experiments for developed vacuum seeder

Suction pressure (mm of Hg)	Provision of vacuum inlets	Type of needle	Type of seed	Number of replications
80 mm of Hg	Location 1 (L1)	0.69 mm (N2)	Knol-khol Chilli	3
		0.60 mm(N3)		
		0.51 mm (N4)		
	Location 2 (L2)	0.69 mm (N2)	Knol-khol Chilli	
		0.60 mm (N3)		
		0.51 mm (N4)		

	Location 3 (L3)	0.69 mm (N2)	Knol-khol Chilli	
		0.60 mm (N3)		
		0.51 mm (N4)		
	Location 4 (L4)	0.69 mm (N2)	Knol-khol Chilli	
		0.60 mm (N3)		
		0.51 mm (N4)		

3.10.7 Working principle of vacuum seeder

Similar to the working principle given in section 3.6.3 instead of moving the seeder unit on platform, the seeder pipe was then moved to the dibbled pro-tray. The seeds were dropped in dibbled cells by cutting off the valve.

3.10.8. Performance evaluation of developed vacuum seeder

The developed vacuum seeder performance was evaluated and observations were taken for the number of cells of pro trays with singles, doubles, triples and missings. The time taken for operation was also recorded.

Chapter-IV

Results& Discussion

Chapter IV

RESULTS AND DISCUSSION

The results of the present study entitled "Design and development of a pro-tray vacuum seeder for crop nursery" conducted at Division of Post-Harvest Technology and Agricultural Engineering, Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru-560089 and in the laboratories of College of Agricultural Engineering, Bapatla during the year 2017- 2018, are given below:

4.1 MOISTURE CONTENT OF SEEDS

The moisture content of seeds were found to be 11.26, 7.78, 7.82, 9.73, 6.5, 5.23 and 10.8 % for chilli, brinjal, tomato, capsicum, cabbage, knol-khol and mari-gold seeds, respectively.

4.2 PHYSICAL PROPERTIES OF SEEDS

Engineering properties of the seeds like linear dimensions, thousand seed weight, bulk density and terminal velocity influence the performance of seed singulation mechanism in terms of pickup, singulation and drop of seeds. Hence these properties were used in designing two important parts viz., seed tray and seed pickup systems of protray vacuum seeder.

4.2.1 Linear dimensions

The length, width, thickness were found to be 4.08±0.03, 3.32±0.04, 0.44±0.01 mm for chilli, 2.78±0.03, 2.55±0.02, 0.28±0.004 mm for brinjal, 3.02±0.04, 2.06±0.02, 0.59±0.01 mm for tomato and 4.28±0.03,3.89±0.02, 0.54±0.01 mm for capsicum seeds, 16.25±0.18, 1.04±0.02, 0.45±0.01 mm for marigold, respectively.

Major and minor diameters were found to be 2.03±0.02, 1.91±0.18 mm and 1.95±0.02, 1.69±0.02 mm for cabbage and knol-khol seeds, respectively.

4.2.2 Geometric mean diameter

Geometric mean diameter of seeds were found to be 1.81±0.01, 1.26±0.01, 1.53±0.01, 2.07±0.01, 1.95±0.02, 1.77±0.02 and 1.93±0.02 mm for chilli, brinjal, tomato, capsicum, cabbage, knol-khol and marigold seeds, respectively.

4.2.3 Sphericity

Sphericity of seeds were found to be 0.44±0.003, 0.45±0.003, 0.51±0.005, 0.48±0.003, 0.96±0.004, 0.91±0.01 and 0.12±0.002 for chilli, brinjal, tomato, capsicum, cabbage, knol-khol and marigold seeds, respectively.

4.2.4 One thousand seed weight

One thousand seed weight were found to be 5.53±0.09, 2.82±0.06, 2.68±0.07, 8.2±0.07, 4.39±0.15, 2.97±0.26 and 1.62±0.06 g for chilli, brinjal, tomato, capsicum, cabbage, knol-khol and marigold seeds, respectively.

4.2.5 Bulk density

Bulk density of seeds were found to be 460.99±4.93, 540.03±8.66, 292.61±3.24, 401.68±4.43, 748±5.52, 643.61±7.73 and 29.72±4.05 kg m^{-3} for chilli, brinjal, tomato, capsicum, cabbage, knol-khol and marigold, respectively.

4.2.6 Terminal velocity

Terminal velocity of chilli, brinjal, tomato, capsicum, cabbage, knol-khol and marigold seeds were found to be 1.82±0.10, 1.84±0.15, 2.12±0.13, 2.06±0.13, 1.9±0.09, 1.66±0.04 and 2.3±0.08 m s^{-1}, respectively.

Table 4.1 Physical and aerodynamic properties of few vegetable and ornamental seeds

	Chilli	Brinjal	Tomato	Capsicum	Marigold
Length, mm	4.08±0.03	2.78±0.03	3.02±0.04	4.28±0.03	16.25±0.18
Width, mm	3.32±0.04	2.55±0.02	2.06±0.02	3.89±0.02	1.04±0.02
Thickness, mm	0.44±0.01	0.28±0.004	0.59±0.01	0.54±0.01	0.45±0.01
Geometric mean diameter, mm	1.81±0.01	1.26±0.01	1.53±0.01	2.07±0.01	1.93±0.02
Sphericity	0.44±0.003	0.45±0.003	0.51±0.005	0.48±0.003	0.12±0.002
One thousand seed weight, g	5.53±0.09	2.82±0.06	2.68±0.07	8.2±0.07	1.62±0.06
Bulk density, kg m^{-3}	460.99±4.93	540.03±8.66	292.61±3.24	401.68±4.43	29.72±4.05
Terminal velocity, m s^{-1}	1.82±0.10	1.84±0.15	2.12±0.13	2.06±0.13	2.3±0.08

Table 4.2 Physical and aerodynamic properties of vegetable seeds (round)

	Cabbage	Knol-khol
Major diameter, mm	2.03±0.02	1.95±0.02
Minor diameter, mm	1.91±0.18	1.69±0.02
Geometric mean diameter, mm	1.95±0.02	1.77±0.02
Sphericity	0.96±0.004	0.91±0.01
One thousand seed weight, g	4.39±0.15	2.97±0.26

Bulk density, kg m^{-3}	748±5.52	643.61±7.73
Terminal velocity, m s^{-1}	1.9±0.09	1.66±0.04

Plate. 4.1 Cylinder type dibbler

Plate. 4.2 Modified vacuum seeder with needles

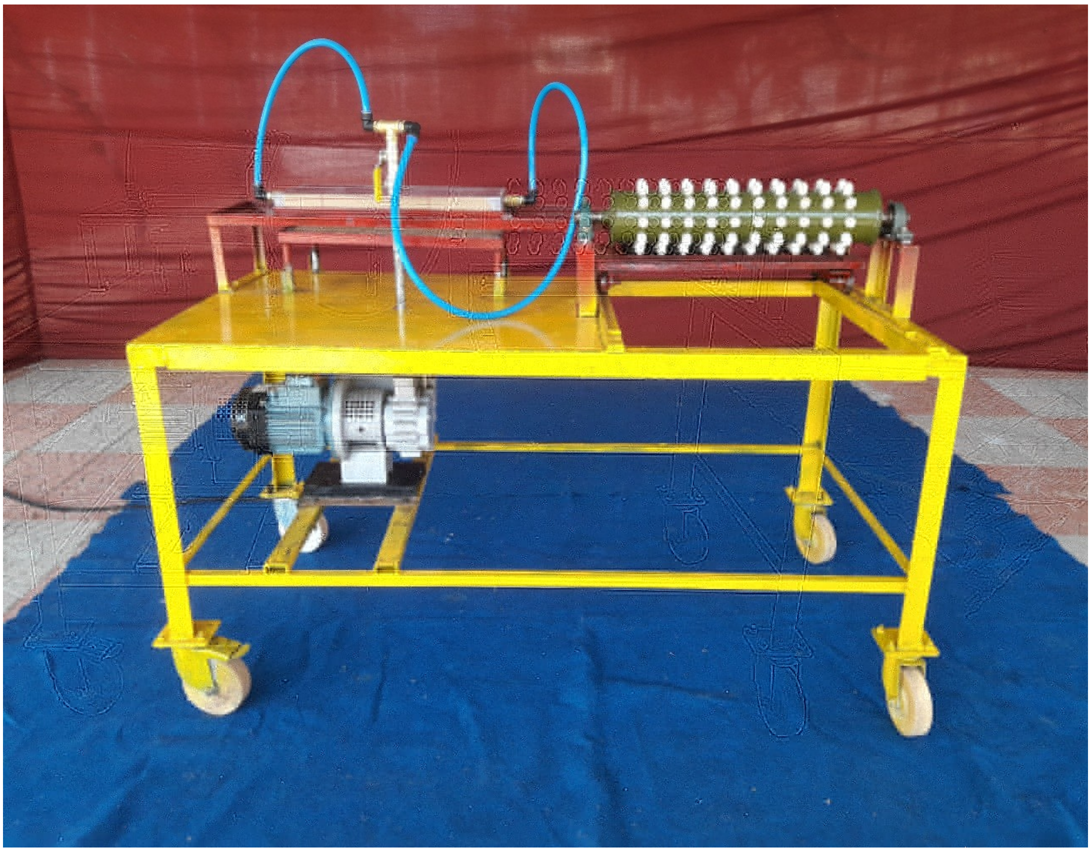


Plate. 4.3 Dibbler cum pro-tray vacuum seeder

4.3 PERFORMANCE EVALUATION OF MODIFIED VACUUM SEEDER

Performance of modified vacuum seeder was evaluated using percentage singles, doubles, triples, miss and total pickup. The effect of orifice size and suction pressure on above parameters for chilli, brinjal, tomato, capsicum, knol-khol and marigold were studied. Four orifice sizes and four suction pressures were selected for performance evaluation. Results of experiments for seeds were studied as presented below:

1. Effect of orifice size, suction pressure and their interaction on percentage of singles
2. Effect of orifice size, suction pressure and their interaction on percentage of doubles
3. Effect of orifice size, suction pressure and their interaction on percentage of triples
4. Effect of orifice size, suction pressure and their interaction on percentage of missings
5. Effect of orifice size, suction pressure and their interaction on percentage of total pickup

4.3.1 Performance evaluation of modified vacuum seeder for chilli seeds

For chilli seeds, results of percentage of singles, doubles, triples, miss and pickup are discussed as follows. The observations of chilli seeds are placed in Appendix I (a).

4.3.1.1 Effect of orifice size, suction pressure and their interaction on percentage of singles

The mean percentage of singles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 41.83, 42.17, 53 and 62.5 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 45, 52.3, 50.6 and 51.5 percent respectively.

Percent of singles decreased with increase in orifice size (Fig 4.1). From the Table 1 (a), it was observed that there was no significant difference between orifice size but there was significant difference between suction pressure and treatments interaction on percent of singles.

It was observed that the treatment (N1P1) had the lowest percent of singles (34%) and the treatment (N4P3) had the highest percent of singles (70%) (Fig. 4.1).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P3, N4P2, N3P2 and N4P4 had the highest percent of singles (70%), (64%), (58%) and (58%) respectively.

4.3.1.2 Effect of orifice size, suction pressure and their interaction on percentage of doubles

The mean percentage of doubles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 36.5, 37.3, 34.5 and 20.5 percent respectively. The mean percentage of doubles of suction pressures 120, 100, 80 and 60 mm of Hg were 37.3, 30.17, 32.83 and 28.5 percent respectively.

Percent of doubles increased with increase in the orifice size (Fig. 4.1). From the Table 1 (b), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between treatments interaction on percent of doubles.

It was observed that the treatment (N1P1) had the lowest percent of doubles (18%) and the treatment (N4P3) had the highest percent of doubles (44.67%) (Fig. 4.2).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P3, N4P4, N4P2 and N4P1 had the lowest percent of doubles (18.67%), (18%), (21.33%) and (24%) respectively.

4.3.1.3 Effect of orifice size, suction pressure and their interaction on percentage of triples

The mean percentage of triples at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 15.67, 13.67, 6 and 3.5 percent respectively. The mean percentage of triples of suction pressures 120, 100, 80 and 60 mm of Hg were 11.5, 10.17, 9.67 and 7.5 percent respectively.

Percent of triples increased with increase in the orifice size (Fig. 4.1). From the Table 1 (c), it was observed that there was no significant difference between orifice size but there was significant difference between suction pressure and treatments on percent of triples.

It was observed that the treatment (N1P1) had the lowest percent of triples (1.33%) and the treatment (N4P4) had the highest percent of triples (20%) (Fig. 4.1).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N4P2, N3P1, N4P1 and N3P4 had the lowest percent of triples (1.33%), (2.67%), (3.33%) and (4.67%) respectively.

4.3.1.4 Effect of orifice size, suction pressure and their interaction on percentage of missings

The mean percentage of missings at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 5.5, 6.83, 6.5 and 13.5 percent respectively. The mean percentage of missings of suction pressures 120, 100, 80 and 60 mm of Hg were 6.17, 7.33, 6.33 and 12.5 percent respectively.

Percent of missings decreased with increase in the orifice size (Fig. 4.1). From the Table 1 (d), it was observed that there was no significant difference between orifice size but there was significant difference between suction pressure and treatments interaction on percent of missings.

It was observed that the treatment (N1P1) had the lowest percent of missings (1.33%) and the treatment (N4P4) had the highest percent of missings (22.67%) (Fig. 4.1).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N1P3, N2P2 and N2P1 had the lowest percent of missings (1.33%), (2.67%), (4%) and (4.67%) respectively.

4.3.1.5 Effect of orifice size, suction pressure and their interaction on percentage of pickup

The mean percentage of pickup at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 94, 93.17, 93.5 and 86.5 percent respectively. The mean percentage of pickup of suction pressures 120, 100, 80 and 60 mm of Hg were 93.83, 92.67, 93.17 and 87.5 percent, respectively.

Percent of pickup varied with different types of orifice size and suction pressure (Fig. 4.1). From the Table 1 (e), it was observed that there was no significant difference between orifice size but there was significant difference between suction pressure and treatments interaction on percent of pickup.

It was observed that the treatment (N1P1) had the lowest percent of pickup (77.33%) and the treatment (N4P4) had the highest percent of pickup (98.67%) (Fig. 4.1).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N2P2, N1P3 and N3P1 had the highest percent of pickup (98.67%), (96%), (95.33%) and (94.67%) respectively.

4.3.2 Performance evaluation of modified vacuum seeder for brinjal seed

4.3.2.1 Effect of orifice size, suction pressure and their interaction on percentage of singles

The mean percentage of singles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 21, 27.5, 33.83 and 53 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 26.83, 36.17, 32.5 and 39.83 percent respectively.

Percent of singles decreased with increase in the orifice size and suction pressure (Fig. 4.2). From the Table 2 (a), it was observed that there was no significant difference between orifice size, suction pressure percent of singles but there was significant difference between interaction of treatments.

It was observed that the treatment (N1P1) had the highest percent of singles (62%) and the treatment (N4P4) had the lowest percent of singles (18%) (Fig. 4.2).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N4P2, N4P3 and N4P1 had the lowest percent of singles (62%), (58.67%), (50%) and (41.33%) respectively.

4.3.2.2 Effect of orifice size, suction pressure and their interaction on percentage of doubles

The mean percentage of doubles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 29.33, 30.17, 30.5 and 36 percent respectively. The mean percentage of doubles of suction pressures 120, 100, 80 and 60 mm of Hg were 29.67, 33.67, 29.33 and 33.33 percent respectively.

Percent of doubles varied with different types of orifice size and suction pressure (Fig. 4.2). From the Table 2 (b), it was observed that there was significant difference between orifice size, suction pressure and interaction of treatments on percent of doubles.

It was observed that the treatment (N4P1) had the lowest percent of doubles (21.33%) and the treatment (N4P4) had the highest percent of doubles (37.33%) (Fig. 4.2).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N2P1, N2P3, N3P3 and N4P3 had the lowest percent of doubles (23.33%), (27.33%), (28%), (28.67%) and (28.67%) respectively.

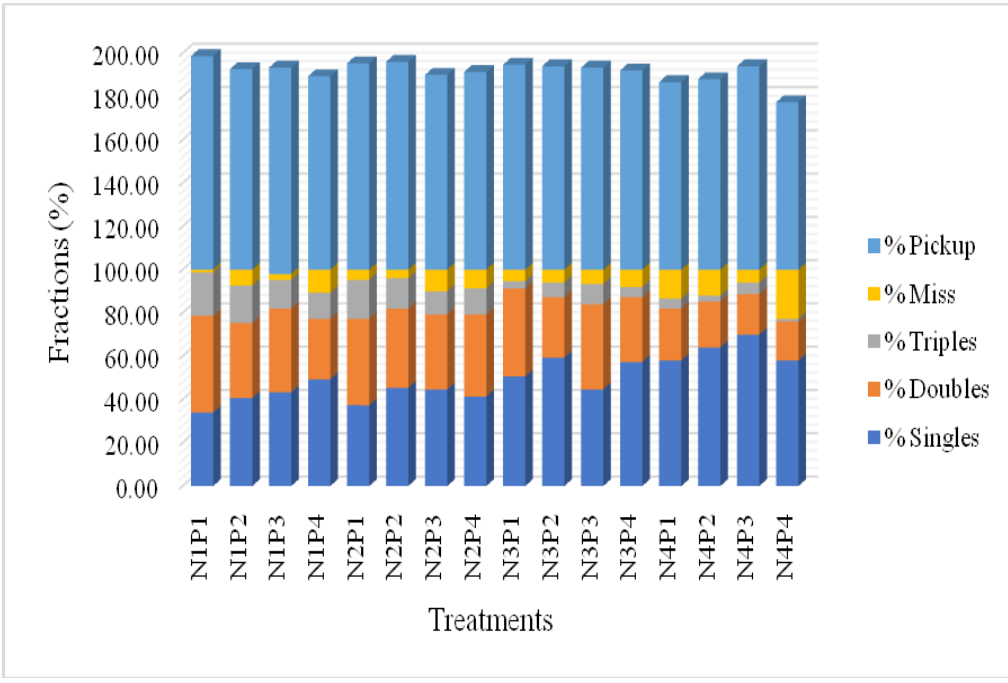


Fig. 4.1 Effect of orifice size, suction pressure of modified vacuum chamber on percentage of singles, doubles, triples, missings and pickup for chilli seed

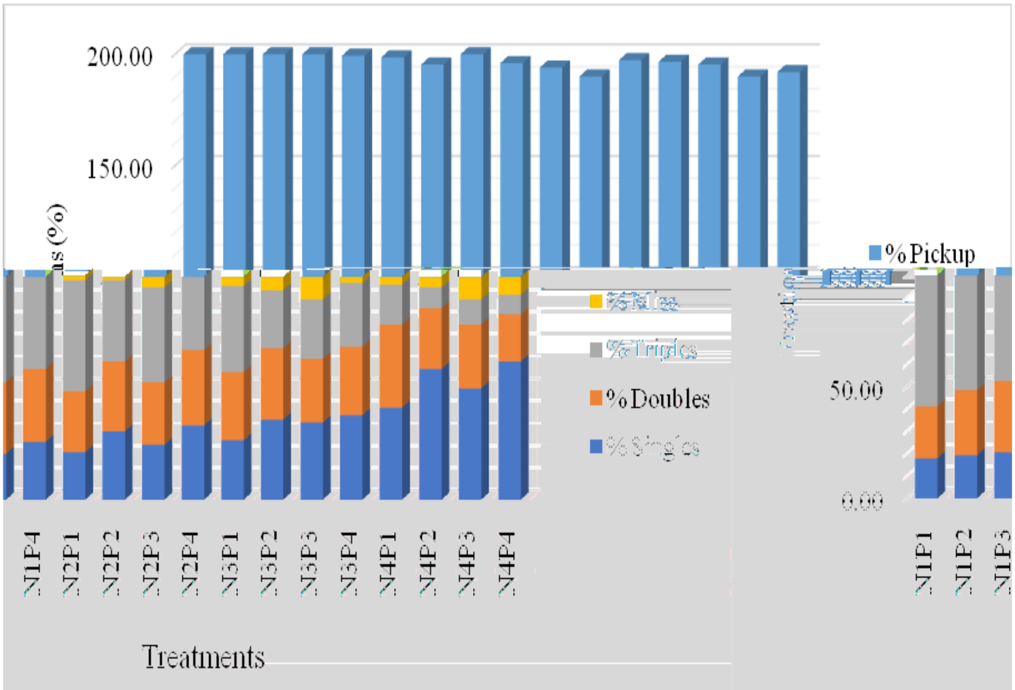


Fig. 4.2 Effect of orifice size, suction pressure of modified vacuum chamber on percentage of singles, doubles, triples, missings and pickup for brinjal seed

4.3.2.3 Effect of orifice size, suction pressure and their interaction on percentage of triples

The mean percentage of triples at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 49.67, 40.5, 30 and 11.83 percent respectively. The mean percentage of triples of suction pressures 120, 100, 80 and 60 mm of Hg were 41.33, 30.83, 32 and 27.83 percent respectively.

Percent of triples varied with different types of orifice size and suction pressure (Fig. 4.2). From the Table 2 (c), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between interaction of needle and suction pressure on percent of triples.

It was observed that the treatment (N4P4) had the lowest percent of triples (8.67%) and the treatment (N1P1) had the highest percent of triples (58.67%) (Fig. 4.2).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N4P2, N4P3 and N4P1 had the lowest percent of triples (62%), (58.67%), (50%) and (41.33%) respectively.

4.3.2.4 Effect of orifice size, suction pressure and their interaction on percentage of missings

The mean percentage of missings at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 0, 2, 5.6 and 6.5 percent respectively. The mean percentage of missings of suction pressures 120, 100, 80 and 60 mm of Hg were 2.3, 3, 6.17 and 2.7 percent respectively.

Percent of missings varied with different types of orifice size and suction pressure (Fig. 4.2). From the Table 2 (d), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between interaction of needle and suction pressure on percent of missings.

It was observed that the treatment (N1P1, N1P2, N1P3, N1P4) had the lowest percent of missings (0%) and the treatment (N3P3, N4P3) had the highest percent of missings (10%) (Fig. 4.2).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N1P2, N1P3 and N1P4 had the lowest percent of missings (0%) for all treatments.

4.3.2.5 Effect of orifice size, suction pressure and their interaction on percentage of pickup

The mean percentage of pickup at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 100, 98, 94.3 and 93.5 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 97.67, 97, 93.83 and 97.33 percent respectively.

Percent of pickup mostly increased with increase in the orifice size (Fig. 4.2). From the Table 2 (e), it was observed that there was no significant difference between orifice size, suction pressure but there was significant difference between interaction on percent of pickup.

It was observed that the treatment (N1P1, N1P2, N1P3, N1P4, N2P4) had the lowest percent of pickup (100%) and the treatment (N3P3, N4P3) had the highest percent of pickup (90%) (Fig. 4.2).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N1P2, N1P3 and N1P4 had the highest percent of pickup (100%).

4.3.3 Performance evaluation of modified vacuum seeder for tomato seed

4.3.3.1 Effect of orifice size, suction pressure and their interaction on percentage of singles

The mean percentage of singles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 36, 48.33, 50 and 55 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 42, 45.83, 50 and 51.5 percent respectively.

Percent of singles decreased with increase in the orifice size (Fig. 4.3). From the Table 3 (a), it was observed that there was no significant difference between orifice size, suction pressure but there was significant difference between interaction on percent of singles.

It was observed that the treatment (N1P1) had the lowest percent of singles (24.67%) and the treatment (N4P1) had the highest percent of singles (57.33%) (Fig. 4.3).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P1, N4P2, N4P3 and N4P4 had the highest percent of singles (57.33%), (54.67%), (54.00%) and (54.00%) respectively.

4.3.3.2 Effect of orifice size, suction pressure and their interaction on percentage of doubles

The mean percentage of doubles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 33.67, 25.67, 28.83 and 19.33 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 35, 30, 22.67 and 19.83 percent respectively.

Percent of doubles increased with increase in the orifice size (Fig. 4.3). From the Table 3 (b), it was observed that there was no significant difference between orifice size, suction pressure but there was significant difference between interaction on percent of doubles.

It was observed that the treatment (N4P3) had the lowest percent of doubles (16.67%) and the treatment (N1P1) had the highest percent of doubles (46%) (Fig. 4.3).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P3, N2P4, N4P4 and N2P3 had the lowest percent of doubles (16.67%), (18%), (18%) and (19.33%) respectively.

4.3.3.3 Effect of orifice size, suction pressure and their interaction on percentage of triples

The mean percentage of triples at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 21.5, 16, 12.17 and 9.17 percent respectively. The mean percentage of triples of suction pressures 120, 100, 80 and 60 mm of Hg were 16.67, 15, 13.83 and 13.33 percent respectively.

Percent of triples increased with increase in the orifice size (Fig. 4.3). From the Table 3 (c), it was observed that there was no significant difference between orifice size but there was significant difference between suction pressure and between treatments on percent of triples.

It was observed that the treatment (N4P2 and N4P4) had the lowest percent of triples (8%) and the treatment (N1P2) had the highest percent of triples (26%) (Fig. 4.3).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P2, N4P4, N4P3 and N3P2 had the lowest percent of triples (8.00%), (8.00%), (8.67%) and (11.33%) respectively.

4.3.3.4 Effect of orifice size, suction pressure and their interaction on percentage of missings

The mean percentage of missings at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 9.67, 9.67, 10.67 and16.5 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 7.17, 9.17, 13.5 and 16.67 percent respectively.

Percent of missings decreased with increase in the orifice size (Fig. 4.3). From the Table 3 (d), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between treatments on percent of missings.

It was observed that the treatment (N2P1) had the lowest percent of missings (4.67%) and the treatment (N4P3) had the highest percent of missings (20.67%) (Fig. 4.3).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N2P1, N1P2, N3P1 and N3P2 had the lowest percent of missings (4.67%), (6.00%), (6.00%) and (6.67%) respectively.

4.3.3.5 Effect of orifice size, suction pressure and their interaction on percentage of pickup

The mean percentage of pickup at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 90.33, 90, 91 and 83.5 percent respectively. The mean percentage of pickup of suction pressures 120, 100, 80 and 60 mm of Hg were 92.83, 90.83, 86.5 and 84.67 percent respectively.

Percent of pickup varied with different types of orifice size and suction pressure (Fig. 4.3). From the Table 3 (e), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between treatments on percent of pickup.

It was observed that the treatment (N4P3) had the lowest percent of pickup (79.33%) and the treatment (N2P1) had the highest percent of pickup (95.33%) (Fig. 4.3).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N2P1, N1P2, N3P1 and N3P2 had the highest percent of pickup (95.33%), (94%), (94%) and (93.33%) respectively.

4.3.4 Performance evaluation of modified vacuum seeder for capsicum seed

4.3.4.1 Effect of orifice size, suction pressure and their interaction on percentage of singles

The mean percentage of singles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 45.33, 52.67, 60.83 and 71.33 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 53.83, 53.17, 58.17 and 65 percent respectively.

Percent of singles varied with different types of orifice size and suction pressure (Fig. 4.4). From the Table 4 (a), it was observed that there was no significant difference betweenneedle size and suction pressure but there was significant difference between treatments on percent of singles.

It was observed that the treatment (N1P1) had the lowest percent of singles (40.67%) and the treatment (N4P4) had the highest percent of singles (79.33%) (Fig. 4.4).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N4P1, N4P3 and N4P2 had the highest percent of singles (79.33%), (70.67%), (68.67%) and (66.67) respectively.

4.3.4.2 Effect of orifice size, suction pressure and their interaction on percentage of doubles

The mean percentage of doubles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 29, 29, 21.33 and 12.67 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 26.67, 26.17, 20.17 and 19 percent respectively.

Percent of doubles decreased with increase in orifice size (Fig. 4.4). From the Table 4 (b), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between treatments on percent of doubles.

It was observed that the treatment (N1P1) had the lowest percent of doubles (5.33%) and the treatment (N4P4) had the highest percent of doubles (34%) (Fig. 4.4).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N4P3, N3P4 and N4P1 had the lowest percent of doubles (5.33%), (12.67%), (16.67%) and (15.33%) respectively.

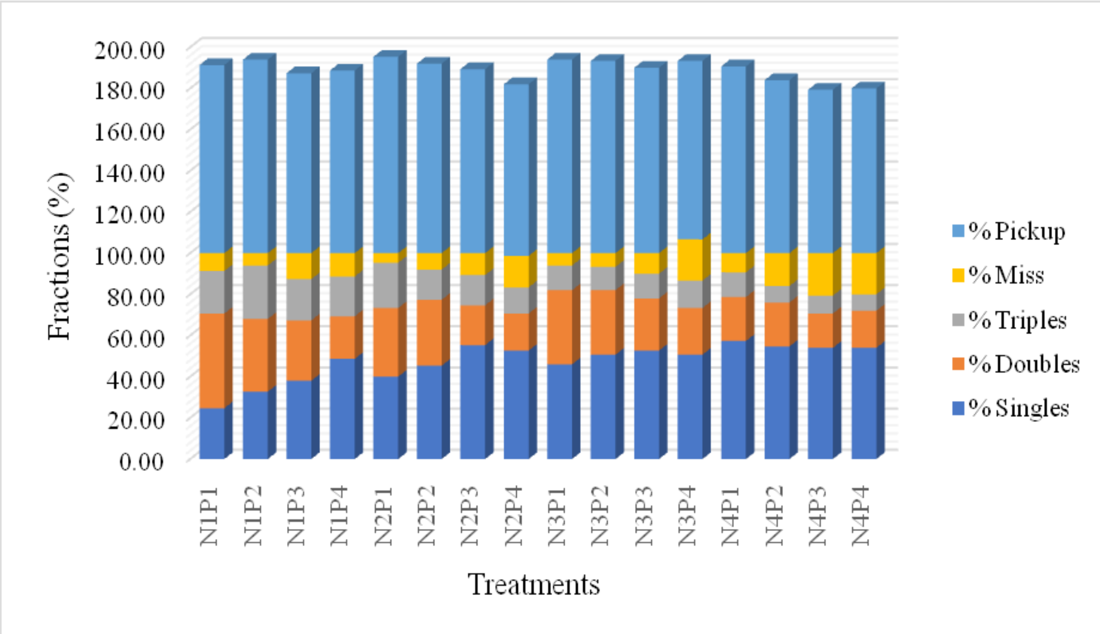


Fig. 4.3 Effect of orifice size, suction pressure of modified vacuum chamber on percentage of singles, doubles, triples, missings and pickup for tomato seed

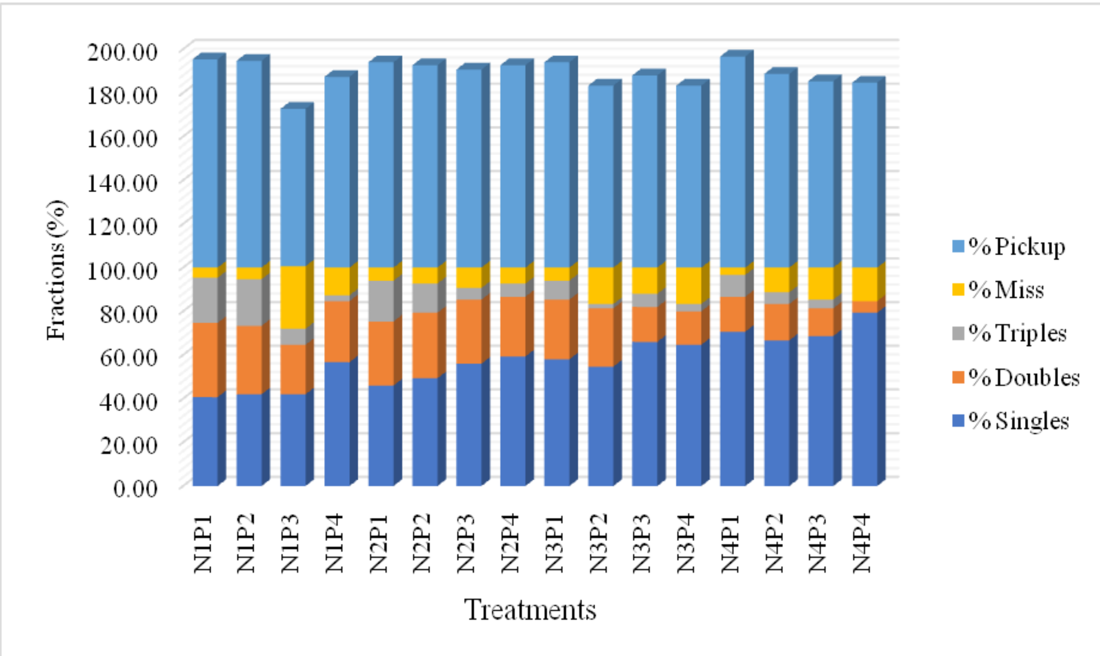


Fig. 4.4 Effect of orifice size, suction pressure of modified vacuum chamber on percentage of singles, doubles, triples, missings and pickup for capsicum seed

4.3.4.3 Effect of orifice size, suction pressure and their interaction on percentage of triples

The mean percentage of triples at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 13, 10.83, 5 and 4.83 percent respectively. The mean percentage of triples of suction pressures 120, 100, 80 and 60 mm of Hg were 14.5, 10.5, 5.67 and 30 percent respectively.

Percent of triples varied with different types of orifice size and suction pressure (Fig. 4.4). From the Table 4 (c), it was observed that there was no significant difference between orifice size and suction pressure and between treatments on percent of triples.

It was observed that the treatment (N4P4) had the lowest percent of triples (0%) and the treatment (N1P2) had the highest percent of triples (21.33%) (Fig. 4.4).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N3P2, N1P4 and N3P4 had the lowest percent of triples (0%), (2.00%), (2,67%) and (3.33%) respectively.

4.3.4.4 Effect of orifice size, suction pressure and their interaction on percentage of missings

The mean percentage of missings at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 12.83, 7.5, 12.83 and 11.17 percent respectively. The mean percentage of missings of suction pressures 120, 100, 80 and 60 mm of Hg were 5, 10.17, 16.17 and 13 percent respectively.

Percent of missings varied with different types of orifice size and suction pressure (Fig. 4.4). From the Table 4 (d), it was observed that there was significant difference between orifice size and there was no significant difference between suction pressure and between treatments on percent of missings.

It was observed that the treatment (N4P1) had the lowest percent of missings (3.33%) and the treatment (N1P3) had the highest percent of missings (28.67%) (Fig. 4.4).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P1, N1P1, N1P2, N2P1 and N3P1 had the lowest percent of missings (3.33%), (4.67%), (5.33%), (6.00%) and (6.00%) respectively.

4.3.4.5 Effect of orifice size, suction pressure and their interaction on percentage of pickup

The mean percentage of pickup at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 87.33, 92.5, 87.17 and 88.83 percent respectively. The mean percentage of pickup of suction pressures 120, 100, 80 and 60 mm of Hg were 95, 89.83, 84 and 87 percent respectively.

Percent of pickup varied with different types of orifice size and suction pressure (Fig. 4.4). From the Table 4 (e), it was observed that there was significant difference between orifice size and there was no significant difference between suction pressure and between treatments on percent of pickup.

It was observed that the treatment (N1P3) had the lowest percent of pickup (72%) and the treatment (N4P1) had the highest percent of pickup (96.67%) (Fig. 4.4).

However when the means of all the factors were compared statistically by LSD, method it was inferred that the treatments N4P1, N1P1, N1P2, N2P1 and N3P1 had the highest percent of pickup (96.67%), (95.33%), (94.67%) and (94.00%) respectively.

4.3.5 Performance evaluation of modified vacuum seeder for knol-khol

4.3.5.1 Effect of orifice size, suction pressure and their interaction on percentage of singles

The mean percentage of singles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 56, 66.17, 73.67 and 79.83 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 66.33, 65.67, 67.5 and 76.17 percent respectively.

Percent of singles increased with increase in orifice size (Fig. 4.5). From the Table 5 (a), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between treatments on percent of singles.

It was observed that the treatment (N1P2) had the lowest percent of singles (50%) and the treatment (N4P4) had the highest percent of singles (89.33%) (Fig. 4.5).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N3P4, N4P3 and N4P1 had the highest percent of singles (89.33%), (78.67%), (78%) and (76.67%) respectively.

4.3.5.2 Effect of orifice size, suction pressure and their interaction on percentage of doubles

The mean percentage of doubles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 20, 7.83, 9.6 and 4.8 percent respectively. The mean percentage of doubles of suction pressures 120, 100, 80 and 60 mm of Hg were 11.83, 13.5, 10 and 70 percent respectively.

Percent of doubles increased with increase in orifice size (Fig. 4.5). From the Table 5 (b), it was observed that there was no significant difference between orifice size and suction pressure but there was significant difference between treatments on percent of doubles.

It was observed that the treatment (N4P4) had the lowest percent of doubles (2.67%) and the treatment (N1P1) had the highest percent of doubles (25.33%) (Fig. 4.5).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P4, N4P3, N3P4, N2P1 and N4P1 had the lowest percent of doubles (2.67%), (4%), (5.33%) and (6.00%) respectively.

4.3.5.3 Effect of orifice size, suction pressure and their interaction on percentage of triples

The mean percentage of triples at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 17.17, 9.5, 6.3 and 0.83 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 9.5, 10.17, 8 and 6.17 percent respectively.

Percent of triples varied with different types of orifice size and suction pressure (Fig. 4.5). From the Table 5 (c), it was observed that there was no significant difference between orifice size and between treatments but there was significant difference between suction pressure on percent of triples.

It was observed that the treatment (N4P1, N4P2, N4P4) had the lowest percent of triples (0%) and the treatment (N1P3) had the highest percent of triples (22%) (Fig. 4.5).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P1, N4P3, N4P4 and N3P4 had the lowest percent of triples (0%), (0%), (0%) and (2.67%) respectively.

4.3.5.4 Effect of orifice size, suction pressure and their interaction on percentage of missings

The mean percentage of missings at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 6.83, 16.5, 10.17 and 14.5 percent respectively. The mean percentage of missings of suction pressures 120, 100, 80 and 60 mm of Hg were 12.17, 10.67, 14.5 and 10.67 percent respectively.

Percent of missings varied with different types of orifice size and suction pressure (Fig. 4.5). From the Table 5 (d), it was observed that there was no significant difference between orifice size and between treatments but there was significant difference between suction pressure on percent of missings.

It was observed that the treatment (N1P1) had the lowest percent of missings (1.33%) and the treatment (N2P1, N2P3) had the highest percent of missings (23.33%) (Fig. 4.5).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N1P3, N2P4 and N3P1 had the lowest percent of missings (1.33%), (3.33%), (6.00%) and (6.67%) respectively.

4.3.5.5 Effect of orifice size, suction pressure and their interaction on percentage of pickup

The mean percentage of pickup at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 93.17, 83.5, 89.67 and 85.5 percent respectively. The mean percentage of pickup of suction pressures 120, 100, 80 and 60 mm of Hg were 87.67, 89.33, 85.5 and 89.3 percent respectively.

Percent of pickup varied with different types of orifice needle and suction pressure (Fig. 4.5). From the Table 5 (e), it was observed that there was no significant difference between orifice size and between treatments but there was significant difference between suction pressure on percent of pickup.

It was observed that the treatment (N1P1) had the lowest percent of pickup (76.67%) and the treatment (N2P3) had the highest percent of pickup (98.67%) (Fig. 4.5).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N1P3, N2P4, N3P1 and N1P2 had the highest percent of pickup (98.67%), (96.67%), (94.00%) and (92.67%) respectively.

4.3.6 Performance evaluation of modified vacuum seeder for marigold

4.3.6.1 Effect of orifice size, suction pressure and their interaction on percentage of singles

The mean percentage of singles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 48.83, 47.33, 50 and 54.67 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 46.83, 53, 50.83 and 50.17 percent respectively.

Percent of singles varied with different types of orifice size and suction pressure (Fig. 4.6). From the Table 6 (a), it was observed that there was significant difference between orifice size, suction pressure and between treatments on percent of singles.

It was observed that the treatment (N2P1) had the lowest percent of singles (42%) and the treatment (N4P3) had the highest percent of singles (61.33%) (Fig. 4.6).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P3, N4P2, N3P2 and N3P4 had the highest percent of singles (61.33%), (54.67%), (54.67%) and (54.00%) respectively.

4.3.6.2 Effect of orifice size, suction pressure and their interaction on percentage of doubles

The mean percentage of doubles at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 25.67, 25.67, 22 and12.17 percent respectively. The mean percentage of doubles of suction pressures 120, 100, 80 and 60 mm of Hg were 23.33, 19.5, 22.83 and 19.83 percent respectively.

Percent of doubles varied with different types of orifice size and suction pressure (Fig. 4.6). From the Table 6 (b), it was observed that there was significant difference between orifice size, suction pressure and between treatments on percent of doubles.

It was observed that the treatment (N4P3) had the lowest percent of doubles (9.33%) and the treatment (N1P1) had the highest percent of doubles (35.33%) (Fig. 4.6).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N4P3, N4P2, N4P1, N4P4 and N4P1 had the lowest percent of doubles (9.33%), (11.33%), (13.33%), (14.67%) and (14.67%) respectively.

4.3.6.3 Effect of orifice size, suction pressure and their interaction on percentage of triples

The mean percentage of triples at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 18.5, 14, 9.67 and 7.83 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 15.33, 10.5, 12.33 and 11.83 percent respectively.

Percent of triples varied with different types of orifice size and suction pressure (Fig. 4.6). From the Table 6 (c), it was observed that there was no significant difference between orifice size and between treatments but there was significant difference between suction pressure on percent of triples.

It was observed that the treatment (N1P4) had the lowest percent of triples (4.67%) and the treatment (N4P4) had the highest percent of triples (24%) (Fig. 4.6).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N3P2, N4P4, N4P3 and N4P2 had the lowest percent of triples (4.67%), (4.67%), (5.33%) and (8.00%) respectively.

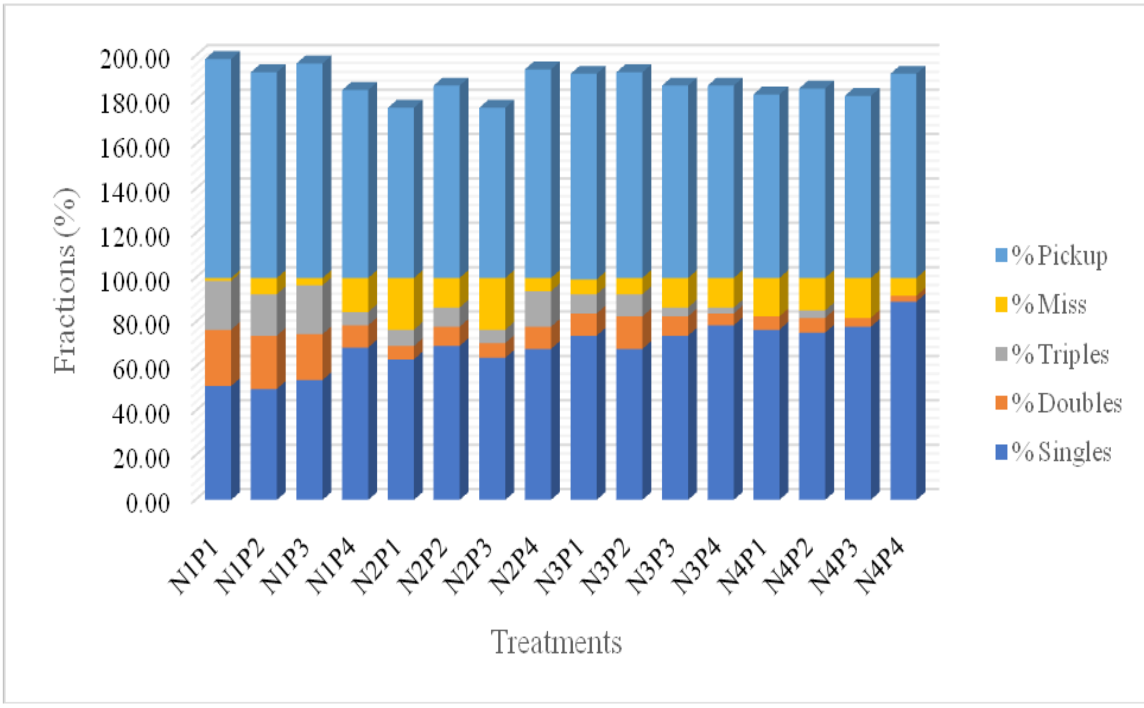


Fig. 4.5 Effect of orifice size, suction pressure of modified vacuum chamber on percentage of singles, doubles, triples, missings and pickup for knol-khol seed

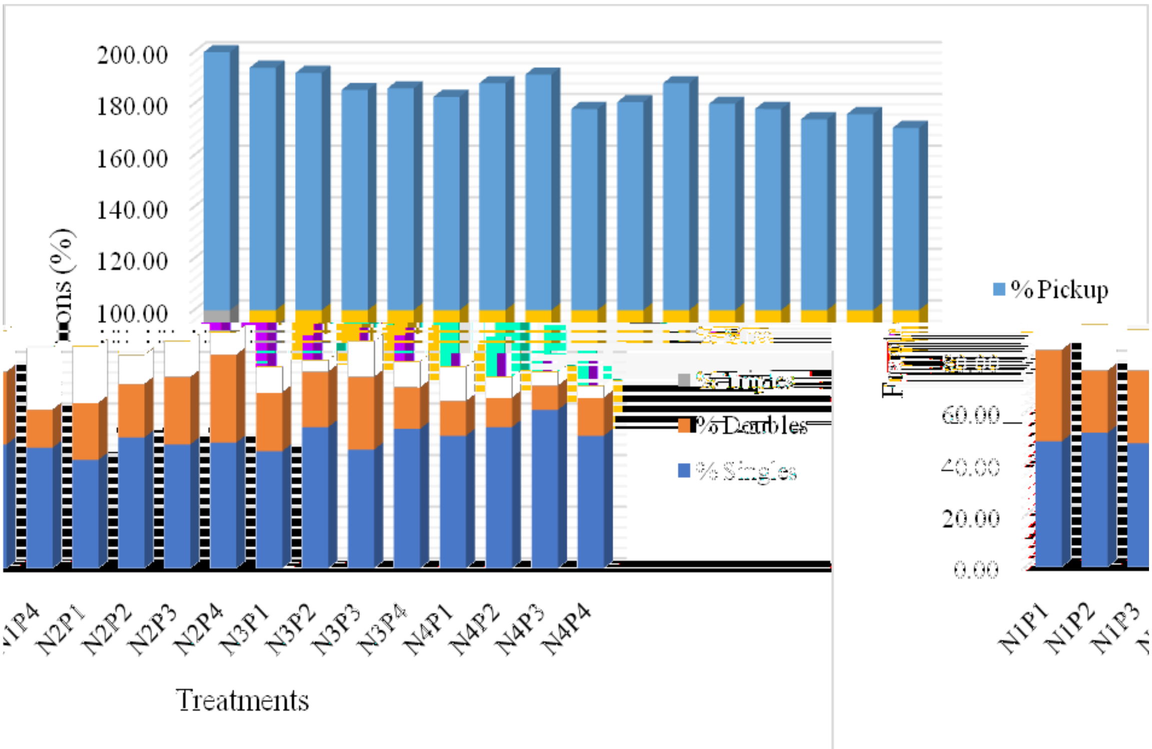


Fig. 4.6 Effect of orifice size, suction pressure of modified vacuum chamber on percentage of singles, doubles, triples, missings and pickup for marigold seed

4.3.6.4 Effect of orifice size, suction pressure and their interaction on percentage of missings

The mean percentage of missings at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 7.17, 13, 18.33 and 25.33 percent respectively. The mean percentage of singles of suction pressures 120, 100, 80 and 60 mm of Hg were 14.5, 17.17, 14 and 18.17 percent respectively.

Percent of missings varied with different types of orifice size and suction pressure (Fig. 4.6). From the Table 6 (d), it was observed that there was no significant difference between orifice size, suction pressure and between treatments on percent of missings.

It was observed that the treatment (N1P1) had the lowest percent of missings (0%) and the treatment (N4P4) had the highest percent of missings (29.33%) (Fig. 4.6).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N1P2, N1P3 and N2P4 had the lowest percent of missings (0%), (6%), (8%) and (8.67%) respectively.

4.3.6.5 Effect of orifice size, suction pressure and their interaction on percentage of pickup

The mean percentage of pickup at different pressures of 0.84, 0.69, 0.60 and 0.51 mm orifice sizes were 100, 98, 94.33 and 93.5 percent respectively. The mean percentage of pickup of suction pressures 120, 100, 80 and 60 mm of Hg were 97.67, 97, 93.83 and 97.33 percent respectively.

Percent of pickup varied with different types of orifice size and suction pressure (Fig. 4.6). From the Table 6 (e), it was observed that there was no significant difference between orifice size, suction pressure but there was significant difference between treatments on percent of pickup.

It was observed that the treatment (N4P4) had the lowest percent of pickup (70.67%) and the treatment (N1P1) had the highest percent of pickup (100%) (Fig. 4.6).

However when the means of all the factors were compared statistically by LSD method it was inferred that the treatments N1P1, N1P2, N1P3 and N1P4 had the highest percent of pickup (100%).

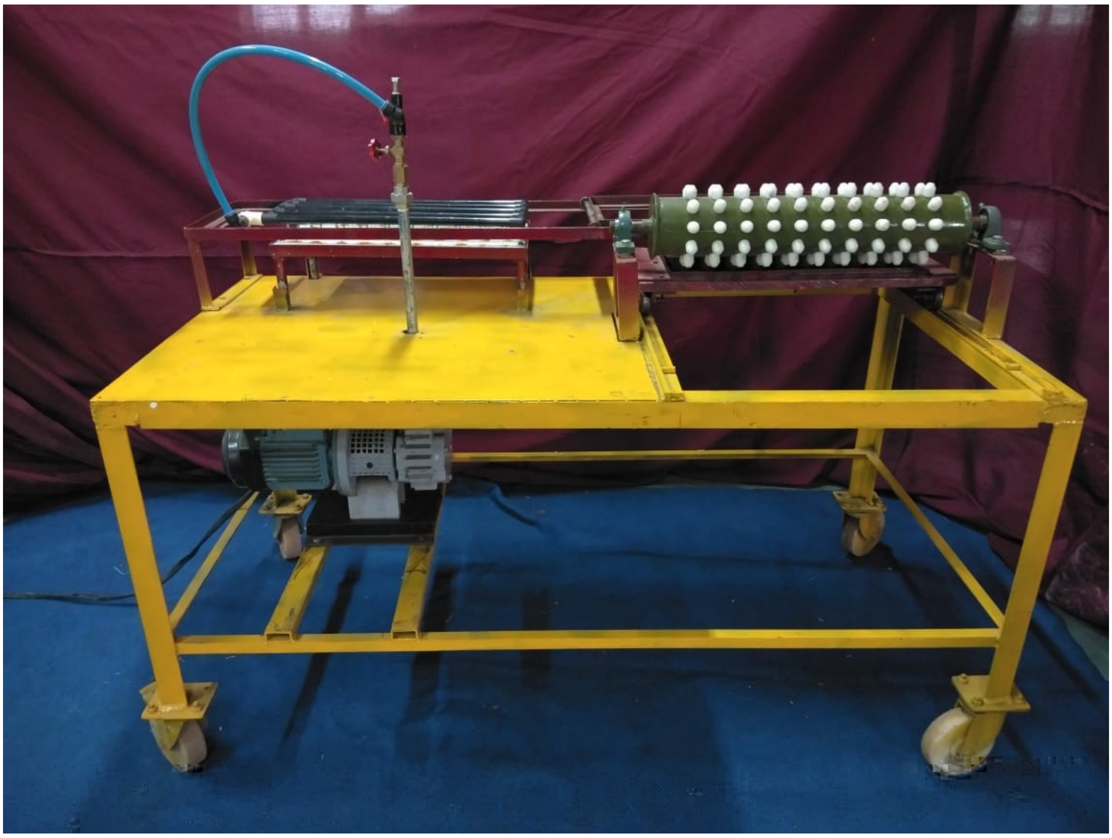


Plate. 4.4 Pipe type vacuum seeder

4.4 PERFORMANCE EVALUATION OF DEVELOPED VACUUM SEEDER

Performance of developed vacuum seeder was evaluated using percentage singles, doubles, triples, miss and pickup. After optimization of design and operational parameters, three needle sizes and one suction pressure were selected for performance evaluation of developed vacuum seeder. The effect of needle size and suction pressure on above parameters for flat seed (chilli) and round seed (knol-khol) was studied at four vacuum inlet locations.

4.4.1 Performance evaluation of developed vacuum seeder with knol-khol seed

4.4.1.1 Effect of orifice size and location of vacuum inlet and their interaction on percent of singles

The mean percentage of singles at different locations of L1, L2, L3 and L4 were 74.67, 68.22, 65.33 and 71.79 percent respectively. The mean percentage of singles of

0.69, 0.60 and 0.51 mm orifice sizes were 56.67, 71, 93.83 and 82.33 percent respectively.

From the Table 7 (a), it was observed that there was no significant difference between orifice sizes, location of inlet and interaction between treatments on percent of singles.

It was observed that the treatment (L1N4) followed by (L2N4) had the highest percent of singles (91.33%) and (83.33%) respectively (Fig. 4.7).

4.4.1.2 Effect of orifice size and location of vacuum inlet and their interaction on percent of doubles

The mean percentage of doubles at different locations of L1, L2, L3 and L4 were 10.44, 14, 12.8 and 8.22 percent respectively. The mean percentage of doubles of 0.69, 0.60 and 0.51 mm orifice sizes were 16.33, 12.17 and 5.67 percent respectively.

From the Table 7 (b), it was observed that there was no significant difference between orifice sizes and interaction between treatments but there was significant difference location of inlet on percent of doubles.

It was observed that the treatment (L1N4) followed by (L4N4) had the lowest percent of doubles (2.67%) and (3.33%) respectively (Fig. 4.7).

4.4.1.3 Effect of orifice size and location of vacuum inlet and their interaction on percent of triples

The mean percentage of triples at different locations of L1, L2, L3 and L4 were 9.78, 14.67, 19.11 and 14.89 percent respectively. The mean percentage of triples of 0.69, 0.60 and 0.51 mm orifice sizes were 22.33, 12.5 and 9 percent respectively.

From the Table 7 (c), it was observed that there was no significant difference between orifice size, location of inlet and interaction between treatments on percent of triples.

It was observed that the treatment (L1N4) followed by (L2N4) and (L4N3) had the lowest percent of triples (2.67%), (8.00%) and (8.00%) respectively (Fig. 4.7).

4.4.1.4 Effect of orifice size and location of vacuum inlet and their interaction on percent of missings

The mean percentage of missings at different locations of L1, L2, L3 and L4 were 4.89, 3.11, 2.67 and 4.67 percent respectively. The mean percentage of missings of 0.69, 0.60 and 0.51 mm orifice sizes were 4.67, 4.33 and 2.50 percent respectively.

From the Table 7 (d), it was observed that there was no significant difference between orifice size, location of inlet and interaction between treatments on percent of missings.

It was observed that the treatment (L2N3) followed by (L2N3) and (L2N4) had the lowest percent of missings (2.00%), (2.67%) and (2.67%) respectively (Fig. 4.7).

4.4.1.5 Effect of orifice size and location of vacuum inlet and their interaction on percent of pickup

The mean percentage of pickup at different locations of L1, L2, L3 and L4 werse 94.89, 96.89, 97.33 and 94.89 percent respectively. The mean percentage of pickup of 0.69, 0.60 and 0.51 mm orifice sizes were 95.33, 95.67 and 97 percent respectively.

From the Table 7 (e), it was observed that there was no significant difference between location of inlet and interaction between treatments on percent of pickup but there was significant difference between oriifce size on pickup percentage.

It was observed that the treatment (L3N2) followed by (L2N3) and (L2N4) had the highest percent of pickup (98.00%), (97.33%) and (97.33%) respectively (Fig. 4.7).

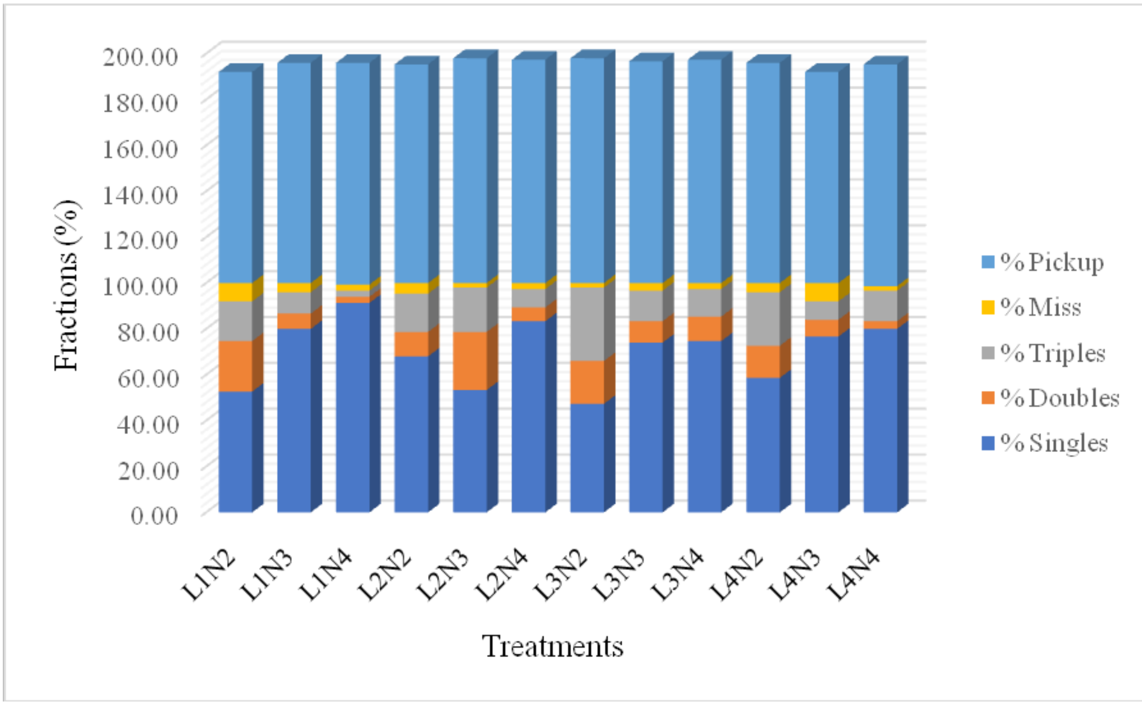


Fig. 4.7 Effect of orifice size, suction pressure of developed vacuum seeder on percentage of singles, doubles, triples, missings and pickup for knol-khol seed

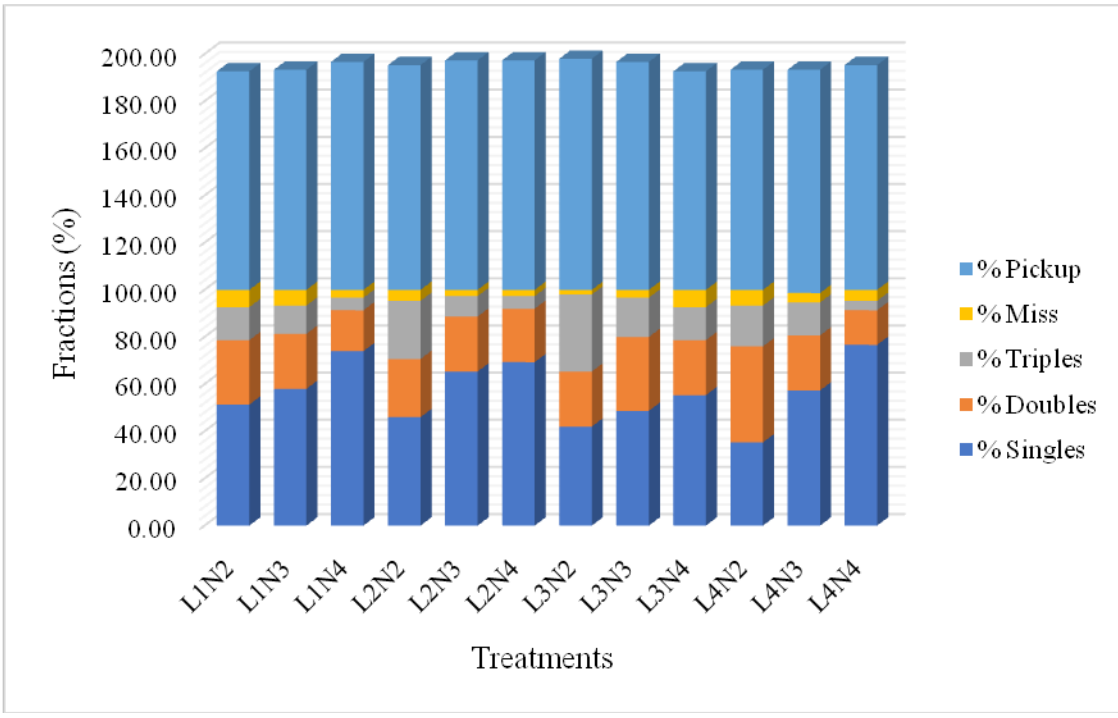


Fig. 4.8 Effect of orifice size, suction pressure of developed vacuum seederon percentage of singles, doubles, triples, missings and pickup for chilli seed

4.4.2 PERFORMANCE EVALUATION OF DEVELOPED VACUUM SEEDER WITH CHILLI SEED

4.4.2.1 Effect of orifice size and location of vacuum inlet and their interaction on percent of singles

The mean percentage of singles at different locations of L1, L2, L3 and L4 were 61.11, 60.22, 48.67 and 56.44 percent respectively. The mean percentage of singles of 0.69, 0.60 and 0.51 mm orifice size were 47.67, 57.33 and 68.83 percent respectively.

From the Table 8 (a), it was observed that there was no significant difference between orifice size, location of inlet and interaction between treatments on percent of singles.

It was observed that the treatment (L4N4) followed by (L1N4) had the highest percent of singles (76.67% and 74%) respectively (Fig. 4.8).

4.4.2.2 Effect of orifice size and location of vacuum inlet and their interaction on percent of doubles

The mean percentage of doubles at different locations of L1, L2, L3 and L4 were 22.67, 23.56, 26 and 26.22 percent respectively. The mean percentage of doubles of 0.69, 0.60 and 0.51 mm orifice sizes were 29, 25.33 and 19.50 percent respectively.

From the Table 8 (b), it was observed that there was no significant difference between orifice size and interaction between treatments but there was significant difference location of inlet on percent of doubles.

It was observed that the treatment (L4N4) followed by (L1N4) had the lowest percent of doubles (14.67%) and (17.33%) respectively (Fig. 4.8).

4.4.2.3 Effect of orifice size and location of vacuum inlet and their interaction on percent of triples

The mean percentage of triples at different locations of L1, L2, L3 and L4 were, 10.44, 12.89, 21.11 and 11.79 percent respectively. The mean percentage of triples of 0.69, 0.60 and 0.51 mm orifice sizes were 22.17, 12.83 and 7.17 percent respectively.

From the Table 8 (c), it was observed that there was no significant difference between orifice size, location of inlet but there was significant difference between interaction between treatments on percent of triples.

It was observed that the treatment (L4N4) followed by (L1N4) and (L2N4) had the lowest percent of triples (4.00%), (5.33%) and (5.33%) respectively (Fig. 4.8).

4.4.2.4 Effect of orifice size and location of vacuum inlet and their interaction on percent of missings

The mean percentage of missings at different locations of L1, L2, L3 and L4 were 5.78, 3.33, 4.22 and 5.11 percent respectively. The mean percentage of missings of 0.69, 0.60 and 0.51 mm orifice sizes were 5.17, 4.17 and 4.50 percent respectively.

From the Table 8 (d), it was observed that there was significant difference between orifice size, location of inlet but there was no significant difference between treatments interaction on percent of missings.

It was observed that the treatment (L3N2) followed by (L2N3) and (L2N4) had the lowest percent of missings (2.00%), (2.67%) and (2.67%) respectively (Fig. 4.8).

4.4.2.5 Effect of orifice size and location of vacuum inlet and their interaction on percent of pickup

The mean percentage of pickup at different locations of L1, L2, L3 and L4 were 94.22, 96.67, 95.78 and 94.44 percent respectively. The mean percentage of pickup of 0.69, 0.60 and 0.51 mm orifice sizes were 94.83, 95.50 and 95.50 percent respectively.

From the Table 8 (e), it was observed that there was significant difference between orifice size, location of inlet on percent of pickup but there was significant difference between interaction of treatments on pickup percentage.

It was observed that the treatment (L3N2) followed by (L2N3) and (L2N4) had the highest percent of pickup (98.00%), (97.33%) and (97.33%) respectively (Fig. 4.8).

Chapter-V

Summary & Conclusions

Chapter V

SUMMARY AND CONCLUSIONS

India ranks second in vegetable production. Today, millions of vegetable and flower transplants are produced annually in greenhouses under carefully controlled environmental conditions for optimizing germination and plant growth. This has become possible mainly through the development of the plug system. Manual sowing of small vegetable seeds in plug trays is an eye-straining and laborious operation, limits the production capacities of vegetable nurseries. Vacuum seeders have not been adopted by marginal growers due to high costs.

To address the above limitations, the present investigation entitled "Design and development of a protray vacuum seeder for crop-nursery" was undertaken with the following objectives:

a. To study engineering properties of selected vegetables and ornamental seeds
b. To design and develop components of protray vacuum seeder
c. To optimize design and operational parameters of seeder
d. To evaluate performance of pro-tray vacuum seeder

The moisture content of seeds were found to be 11.26, 7.78, 7.82, 9.73, 6.5, 5.23 and 10.8 % for chilli, brinjal, tomato, capsicum and knol-khol seeds. The physical properties namely linear dimensions, geometric mean diameter, sphericity, one thousand seed weight, bulk density and terminal velocity for selected vegetable and ornamental seeds viz., chilli, brinjal, tomato, capsicum, cabbage, knol-khol and marigold were determined to design and develop a protray vacuum seeder to be used in crop nursery. Linear dimensions of seeds were measured by using electronic microscope assisted with Q-capture software and other properties were determined by following standard procedures. The length, width, thickness, geometric mean diameter and sphericity were found to be 4.08±0.03, 3.32±0.04, 0.44±0.01, 1.81±0.01 mm, 0.44±0.003 for chilli, 2.78±0.03, 2.55±0.02, 0.28±0.004, 1.26±0.01 mm, 0.45±0.003 for brinjal, 3.02±0.04, 2.06±0.02, 0.59±0.01, 1.53±0.01 mm, 0.51±0.005 for tomato and 4.28±0.03, 3.89±0.02, 0.54±0.01, 2.07±0.01 mm, 0.48±0.003 for capsicum seeds, 16.25±0.18, 1.04±0.02, 0.45±0.01, 1.93±0.02 mm, 0.12±0.002 for marigold respectively. Major and minor diameters, geometric mean diameter and sphericity were found to be 2.03±0.02, 1.91±0.18, 0.91±0.01 mm and 0.12±0.002 for cabbage seeds and 1.95±0.02, 1.69±0.02, 1.77±0.02 mm and 0.91±0.01 for knol-khol seeds, respectively. The one thousand seed weight and bulk density were found to be 5.53±0.09, 2.82±0.06, 2.68±0.07, 8.2±0.07, 4.39±0.15, 2.97±0.26, 1.62±0.06 g and 460.99±4.93, 540.03±8.66, 292.61±3.24, 401.68±4.43, 401.68±4.43, 748±5.52, 643.61±7.73 and 29.72±4.05 kg m^{-3} for chilli, brinjal, tomato, capsicum and knol-khol seeds, respectively. Terminal velocity of chilli, brinjal, tomato, capsicum and knol-khol seeds were found to be 1.82±0.10, 1.84±0.15, 2.12±0.13, 2.06±0.13, 1.9±0.09, 1.66±0.04 and 2.3±0.08 m s^{-1}, respectively.

Experiments were conducted to optimize the design and operational parameters viz., orifice size and suction pressure i) Orifice size (0.84, 0.69, 0.6 and 0.51 mm), ii) Suction pressure (120, 100, 80 and 60 mm of Hg) with chilli, brinjal, tomato, capsicum, knol-khol and mari-gold for the modified vacuum chamber seeder.

Based on physical, aerodynamic properties and optimized design and operational parameters, a pipe type vacuum seeder was designed and developed.

The performance of developed vacuum seeder was evaluated for percent singles, doubles, triples, missings and pickup for flat seed (chilli) and round seed (knol-khol). It was concluded that

1. Highest percent of singles, doubles, triples, missings and pickup for knol-khol seed was 91.33, 2.67, 2.67, 2.67 and 96.67 % when vacuum inlet was provided at corner of pipe followed by 83.33, 6, 8, 2.67 % when vacuum inlet was provided at diagonal ends of pipe with 0.51 mm orifice size at a pressure of 80 mm of Hg.

2. Highest percent of singles, doubles, triples, missings and pickup for chilli seed was 76.67, 14.67, 4, 4.67 and 95.33 % when vacuum inlet at center on both side provided at of pipe followed by 74, 17.33, 5.33, 96.67 % when vacuum inlet was provided at diagonal ends of pipe with 0.51 mm orifice size and at a pressure of 80 mm of Hg.

3. Tube type seeder was designed and developed, it consists of rotary dibbler having nylon pegs 10 along the circumference and 10 numbers in rows. The seeder consisted of tubes fitted with 50 nozzles of 0.51 mm orifice size and connected to vacuum pump. The seed pickup and drop were controlled by vacuum. The seeder was operated by 1-phase, 1 hp, 350 lpm oil lubricated pump. Capacity of seeder 100 trays per hour. Cost of seeder was Rs. 88,300/-.

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Appendices

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	3,518.917	1,172.972	21.262	0.00000	6.205	3.032	2.144
Suction pressure	3	396.917	132.306	2.398	0.08624	N/A	3.032	2.144
Needle*Suction pressure	9	786.083	87.343	1.583	0.16251	N/A	6.064	4.288
Error	32	1,765.333	55.167					

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	2,244.250	748.083	12.264	0.00002	6.524	3.189	2.255
Suction pressure	3	534.917	178.306	2.923	0.04884	6.524	3.189	2.255
Needle* Suction pressure	9	390.750	43.417	0.712	0.69402	N/A	6.377	4.509
Error	32	1,952.000	61.000					
Total	47	5,121.917						

Appendix- A

Table 1 (a). ANOVA on effect of needle size and suction pressure of chilli seed on percentage of singles for modified vacuum chamber

Table 1 (b). ANOVA on effect of needle size and suction pressure of chilli seed on percentage of doubles for modified vacuum chamber

Table 1 (c). ANOVA on effect of needle size and suction pressure of chilli seed on percentage of triples for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	1,241.583	413.861	18.670	0.00000	3.933	1.922	1.359
Suction pressure	3	99.583	33.194	1.497	0.23394	N/A	1.922	1.359
Needle* Suctionpressure	9	205.417	22.824	1.030	0.43851	N/A	3.844	2.718
Error	32	709.333	22.167					
Total	47	2,255.917						

Table 1 (d). ANOVA on effect of needle size and suction pressure of chilli seed on percentage of missings for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	481.000	160.333	11.590	0.00003	3.107	1.518	1.074
Suction pressure	3	321.667	107.222	7.751	0.00050	3.107	1.518	1.074
Needle* Suction pressure	9	362.333	40.259	2.910	0.01234	6.214	3.037	2.147
Error	32	442.667	13.833					
Total	47	1,607.667						

Table 1 (e). ANOVA on effect of needle size and suction pressure of chilli seed on percentage of pickup for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	452.250	150.750	9.994	0.00008	3.244	1.586	1.121
Suction pressure	3	302.917	100.972	6.694	0.00124	3.244	1.586	1.121
Needle* Suction pressure	9	356.083	39.565	2.623	0.02142	6.489	3.171	2.242
Error	32	482.667	15.083					
Total	47	1,593.917						

Appendix - B

Table 2 (a). ANOVA on effect of needle size and suction pressure of brinjal seed on percentage of singles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	6,866.000	2,288.667	34.373	0.00000	6.816	3.331	2.356
Suction pressure	3	1,106.667	368.889	5.540	0.00353	6.816	3.331	2.356
Needle* Suction pressure	9	271.333	30.148	0.453	0.89490	N/A	6.662	4.711
Error	32	2,130.667	66.583					
Total	47	10,374.667						

Table 2 (b). ANOVA on effect of needle size and suction pressure of brinjal seed on percentage of doubles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	332.667	110.889	1.331	0.28164	N/A	3.727	2.635
Suction pressure	3	193.333	64.444	0.773	0.51750	N/A	3.727	2.635
Needle* Suction pressure	9	347.333	38.593	0.463	0.88830	N/A	7.454	5.270
Error	32	2,666.667	83.333					
Total	47	3,540.000						

Table 2 (c). ANOVA on effect of needle size and suction pressure of brinjal seed on percentage of triples for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	9,492.667	3,164.222	55.190	0.00000	6.325	3.091	2.186
Suction pressure	3	1,222.000	407.333	7.105	0.00086	6.325	3.091	2.186
Needle* Suction pressure	9	242.667	26.963	0.470	0.88361	N/A	6.182	4.372
Error	32	1,834.667	57.333					
Total	47	12,792.000						

Table 2 (d). ANOVA on effect of needle size and suction pressure of brinjal seed on percentage of missings for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	338.250	112.750	12.645	0.00001	2.494	1.219	0.862
Suction pressure	3	112.917	37.639	4.221	0.01268	2.494	1.219	0.862
Needle* Suction pressure	9	97.417	10.824	1.214	0.32095	N/A	2.438	1.724
Error	32	285.333	8.917					
Total	47	833.917						

Table 2 (e). ANOVA on effect of needle size and suction pressure of brinjal seed on percentage of pickup for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	338.250	112.750	12.645	0.00001	2.494	1.219	0.862
Suction pressure	3	112.917	37.639	4.221	0.01268	2.494	1.219	0.862
Needle* Suction pressure	9	97.417	10.824	1.214	0.32095	N/A	2.438	1.724
Error	32	285.333	8.917					
Total	47	833.917						

Appendix - C

Table 3 (a). ANOVA on effect of needle size and suction pressure of tomato seed on percentage of singles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	2,344.000	781.333	14.425	0.00000	6.148	3.005	2.125
Suction pressure	3	662.000	220.667	4.074	0.01472	6.148	3.005	2.125
Needle* Suction pressure	9	783.333	87.037	1.607	0.15536	N/A	6.009	4.249
Error	32	1,733.333	54.167					
Total	47	5,522.667						

Table 3 (b). ANOVA on effect of needle size and suction pressure of tomato seed on percentage of doubles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	1,299.583	433.194	8.664	0.00024	5.907	2.887	2.041
Suction pressure	3	1,716.917	572.306	11.446	0.00003	5.907	2.887	2.041
Needle* Suction pressure	9	558.750	62.083	1.242	0.30561	N/A	5.774	4.082
Error	32	1,600.000	50.000					
Total	47	5,175.250						

Table 3 (c). ANOVA on effect of needle size and suction pressure of tomato seed on percentage of triples for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	1,019.583	339.861	7.695	0.00052	5.552	2.713	1.918
Suction pressure	3	78.917	26.306	0.596	0.62250	N/A	2.713	1.918
Needle* Suction pressure	9	196.083	21.787	0.493	0.86805	N/A	5.426	3.837
Error	32	1,413.333	44.167					

Total	47	2,707.917		

Table 3 (d). ANOVA on effect of needle size and suction pressure of tomato seed on percentage of missings for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	388.250	129.417	5.282	0.00450	4.135	2.021	1.429
Suction pressure	3	658.250	219.417	8.956	0.00019	4.135	2.021	1.429
Needle* Suction pressure	9	222.750	24.750	1.010	0.45248	N/A	4.041	2.858
Error	32	784.000	24.500					
Total	47	2,053.250						

Table 3 (e). ANOVA on effect of needle size and suction pressure of tomato seed on percentage of pickup for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	440.250	146.750	4.153	0.01358	4.966	2.427	1.716
Suction pressure	3	512.917	170.972	4.839	0.00689	4.966	2.427	1.716
Needle* Suction pressure	9	144.083	16.009	0.453	0.89471	N/A	4.853	3.432
Error	32	1,130.667	35.333					
Total	47	2,227.917						

Appendix- D

Table 4 (a). ANOVA on effect of needle size and suction pressure of capsicum seed on percentage of singles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	4,486.250	1,495.417	46.610	0.00000	4.732	2.312	1.635
Suction pressure	3	1,066.917	355.639	11.085	0.00004	4.732	2.312	1.635
Needle* Suction pressure	9	326.083	36.231	1.129	0.37156	N/A	4.625	3.270
Error	32	1,026.667	32.083					
Total	47	6,905.917						

Table 4 (b). ANOVA on effect of needle size and suction pressure of capsicum seed on percentage of doubles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	2,178.667	726.222	24.687	0.00000	4.531	2.214	1.566
Suction pressure	3	570.000	190.000	6.459	0.00152	4.531	2.214	1.566
Needlle* Suction pressure	9	286.000	31.778	1.080	0.40352	N/A	4.428	3.131
Error	32	941.333	29.417					
Total	47	3,976.000						

Table 4 (c). ANOVA on effect of needle size and suction pressure of capsicum seed on percentage of triples for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	616.333	205.444	18.964	0.00000	2.750	1.344	0.950
Suction pressure	3	939.000	313.000	28.892	0.00000	2.750	1.344	0.950
Needlle*	9	457.667	50.852	4.694	0.00051	5.499	2.687	1.900

Suction pressure								
Error	32	346.667	10.833					
Total	47	2,359.667						

Table 4 (d). ANOVA on effect of needle size and suction pressure of capsicum seed on percentage of missings for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	227.667	75.889	2.294	0.09671	N/A	2.348	1.660
Suction pressure	3	808.333	269.444	8.144	0.00036	4.805	2.348	1.660
Needlle*Suction pressure	9	833.000	92.556	2.798	0.01530	9.610	4.696	3.321
Error	32	1,058.667	33.083					
Total	47	2,927.667						

Table 4 (e). ANOVA on effect of needle size and suction pressure of capsicum seed on percentage of pickup for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	220.917	73.639	2.338	0.09216	N/A	2.291	1.620
Suction pressure	3	788.250	262.750	8.341	0.00031	4.688	2.291	1.620
Needle*suction pressure	9	790.750	87.861	2.789	0.01555	9.377	4.583	3.240
Error	32	1,008.000	31.500					
Total	47	2,807.917						

Appendix - E

Table 5 (a). ANOVA on effect of needle size and suction pressure of knol-khol seed on percentage of singles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	3,793.667	1,264.556	26.118	0.00000	5.813	2.841	2.009
Suction pressure	3	861.667	287.222	5.932	0.00245	5.813	2.841	2.009
Needle*Suction pressure	9	427.000	47.444	0.980	0.47479	N/A	5.681	4.017
Error	32	1,549.333	48.417					
Total	47	6,631.667						

Table 5 (b). ANOVA on effect of needle size and suction pressure of knol-khol seed on percentage of doubles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	1,561.667	520.556	23.136	0.00000	3.962	1.936	1.369
Suction pressure	3	279.000	93.000	4.133	0.01386	3.962	1.936	1.369
Needle* Suction pressure	9	351.000	39.000	1.733	0.12179	N/A	3.873	2.739
Error	32	720.000	22.500					
Total	47	2,911.667						

Table 5 (c). ANOVA on effect of needle size and suction pressure of knol-khol seed on percentage of triples for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	1,674.917	558.306	19.939	0.00000	4.420	2.160	1.528
Suction pressure	3	113.583	37.861	1.352	0.27499	N/A	2.160	1.528
Needle*Suction pressure	9	725.417	80.602	2.879	0.01310	8.841	4.320	3.055
Error	32	896.000	28.000					

Total	47	3,409.917		

Table 5 (d). ANOVA on effect of needle size and suction pressure of knol-khol seed on percentage ofmissings for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	678.667	226.222	4.936	0.00627	5.655	2.764	1.954
Suction pressure	3	118.000	39.333	0.858	0.47274	N/A	2.764	1.954
Needle*Suction pressure	9	1,176.667	130.741	2.853	0.01377	11.311	5.528	3.909
Error	32	1,466.667	45.833					
Total	47	3,440.000						

Table 5 (e). ANOVA on effect of needle size and suction pressure of knol-khol seed on percentage of pickup for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	671.583	223.861	4.938	0.00626	5.624	2.749	1.944
Suction pressure	3	118.917	39.639	0.874	0.46458	N/A	2.749	1.944
Needle*Suction pressure	9	1,162.750	129.194	2.850	0.01384	11.249	5.497	3.887
Error	32	1,450.667	45.333					
Total	47	3,403.917						

Appendix– F

Table 6 (a). ANOVA on effect of needle size and suction pressure of marigold seed on percentage of singles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	360.917	120.306	2.224	0.10439	N/A	3.002	2.123
Suction pressure	3	234.917	78.306	1.448	0.24723	N/A	3.002	2.123
Needle*Suction pressure	9	363.417	40.380	0.747	0.66430	N/A	6.005	4.246
Error	32	1,730.667	54.083					
Total	47	2,689.917						

Table 6 (b). ANOVA on effect of needle size and suction pressure of marigold seed on percentage of doubles for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	1,464.250	488.083	8.664	0.00024	6.270	3.064	2.167
Suction pressure	3	142.250	47.417	0.842	0.48115	N/A	3.064	2.167
Needle*Suction pressure	9	1,112.083	123.565	2.193	0.04954	12.540	6.128	4.333
Error	32	1,802.667	56.333					
Total	47	4,521.250						

Table 6 (c). ANOVA on effect of needle size and suction pressure of marigold seed on percentage of triples for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	816.667	272.222	13.279	0.00001	3.782	1.848	1.307

Suction pressure	3	150.000	50.000	2.439	0.08248	N/A	1.848	1.307
Needle*Suction pressure	9	549.333	61.037	2.977	0.01086	7.565	3.697	2.614
Error	32	656.000	20.500					
Total	47	2,172.000						

Table 6 (d). ANOVA on effect of needle size and suction pressure of marigold seed on percentage ofmissings for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	2,154.917	718.306	42.461	0.00000	3.436	1.679	1.187
Suction pressure	3	147.583	49.194	2.908	0.04963	3.436	1.679	1.187
Needle*Suction pressure	9	560.083	62.231	3.679	0.00296	6.872	3.358	2.375
Error	32	541.333	16.917					
Total	47	3,403.917						

Table 6 (e). ANOVA on effect of needle size and suction pressure of marigold seed on percentage of pickup for modified vacuum chamber

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Needle	3	338.250	112.750	12.645	0.00001	2.494	1.219	0.862
Suction pressure	3	112.917	37.639	4.221	0.01268	2.494	1.219	0.862
Needle*Suction pressure	9	97.417	10.824	1.214	0.32095	N/A	2.438	1.724
Error	32	285.333	8.917					
Total	47	833.917						

Appendix - G

Table 7 (a). ANOVA on effect of vacuum inlet location and suction needleof knol-khol seed on percentage ofsingles for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	448.889	149.630	5.302	0.00601	5.199	2.504	1.771
Needle	2	3,970.667	1,985.333	70.346	0.00000	4.503	2.169	1.534
Location of vacuum inlet* Needle	6	1,999.111	333.185	11.806	0.00000	9.006	4.338	3.067
Error	24	677.333	28.222					
Total	35	7,096.000						

Table 7 (b). ANOVA on effect of vacuum inlet location and suction needleof knol-khol seed on percentage ofdoubles for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	179.889	59.963	2.570	0.07789	N/A	2.277	1.610
Needle	2	693.556	346.778	14.862	0.00006	4.094	1.972	1.394
Location of vacuum inlet* Needle	6	869.111	144.852	6.208	0.00049	8.189	3.944	2.789
Error	24	560.000	23.333					
Total	35	2,302.556						

Table 7 (c). ANOVA on effect of vacuum inlet location and suction needleof knol-khol seed on percentage of triples for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	393.222	131.074	5.811	0.00392	4.648	2.239	1.583
Needle	2	1,146.889	573.444	25.424	0.00000	4.025	1.939	1.371

Location of vacuum inlet* Needle	6	501.111	83.519	3.703	0.00953	8.051	3.878	2.742
Error	24	541.333	22.556					
Total	35	2,582.556						

Table 7 (d). ANOVA on effect of vacuum inlet location and suction needleof knol-khol seed on percentage ofmissings for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	33.222	11.074	3.115	0.04502	1.846	0.889	0.629
Needle	2	32.667	16.333	4.594	0.02046	1.598	0.770	0.544
Location of vacuum inlet* Needle	6	83.778	13.963	3.927	0.00711	3.197	1.540	1.089
Error	24	85.333	3.556					
Total	35	235.000						

Table 7 (e). ANOVA on effect of vacuum inlet location and suction needleof knol-khol seed on percentage of pickup for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	45.333	15.111	3.778	0.02369	1.957	0.943	0.667
Needle	2	18.667	9.333	2.333	0.11858	N/A	0.816	0.577
Location of vacuum inlet* Needle	6	72.000	12.000	3.000	0.02481	3.390	1.633	1.155
Error	24	96.000	4.000					
Total	35	232.000						

Appendix– H

Table 8 (a). ANOVA on effect of vacuum inlet location and suction needleof chilli seed on percentage ofsingles for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	867.889	289.296	5.838	0.00383	6.890	3.318	2.347
Needle	2	3,809.556	1,904.778	38.437	0.00000	5.967	2.874	2.032
Location of vacuum inlet* Needle	6	771.778	128.630	2.596	0.04407	11.933	5.748	4.064
Error	24	1,189.333	49.556					
Total	35	6,638.556						

Table 8 (b). ANOVA on effect of vacuum inlet location and suction needleof chilli seed on percentage ofdoubles for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	84.778	28.259	0.974	0.42111	N/A	2.539	1.795
Needle	2	550.889	275.444	9.498	0.00091	4.564	2.198	1.555
Location of vacuum inlet* Needle	6	786.889	131.148	4.522	0.00335	9.129	4.397	3.109
Error	24	696.000	29.000					
Total	35	2,118.556						

Table 8 (c). ANOVA on effect of vacuum inlet location and suction needleof chilli seed on percentage oftriples for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	624.333	208.111	6.689	0.00193	5.459	2.629	1.859
Needle	2	1,376.889	688.444	22.129	0.00000	4.728	2.277	1.610
Location of vacuum inlet* Needle	6	288.000	48.000	1.543	0.20714	N/A	4.554	3.220

Error	24	746.667	31.111						
Total	35	3,035.889							

Table 8 (d). ANOVA on effect of vacuum inlet location and suction needleof chilli seed on percentage ofmissings for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	30.556	10.185	1.763	0.18114	N/A	1.133	0.801
Needle	2	6.222	3.111	0.538	0.59053	N/A	0.981	0.694
Location of vacuum inlet* Needle	6	87.111	14.519	2.513	0.04967	4.075	1.963	1.388
Error	24	138.667	5.778					
Total	35	262.556						

Table 8 (e). ANOVA on effect of vacuum inlet location and suction needleof chilli seed on percentage ofpickup for developed vacuum seeder

Source of variation	DF	SS	MSS	Fcal	Sig	C.D.	SED	SEM
Location of vacuum inlet	3	35.889	11.963	2.153	0.11990	N/A	1.111	0.786
Needle	2	3.556	1.778	0.320	0.72920	N/A	0.962	0.680
Location of vacuum inlet* Needle	6	84.444	14.074	2.533	0.04821	3.996	1.925	1.361
Error	24	133.333	5.556					
Total	35	257.222						

Appendix – I

Specifications and cost of developed vacuum seeder

S.No	Material	Size	Quantity	Cost
1	MS angle	40×40×6 mm	60 kg	4000
2	‘C’ Channel	75×40×5 mm	20 kg	1000
3	Dibbler cylinder	115×60×5 mm	1 p	1500
4	MS angle	25×25×5 mm	10 kg	1000
5	Nylon pegs	25 mm Ø	50	5000
6	MS shaft 25 Ø	625 mm	1 p	1000
7	Caster wheels	6”×2” swivel type	4 No.	3000
8	Pressure gauge	150 bar	1 No.	500
9	Vacuum pump	350 lpm	1 No.	40000
10	Pipes	15 ft	6 No.	500
11	T-joints	½”	6 No.	30
12	Threaded elbow	½”	2 No.	200
13	Elbow	½”	4 No.	20
14	Pipe (PV tube)	16 mm Ø	5 m	300
15	Movable trolley for dibbler	660×335 mm	1 No.	2000
16	GI pipe	½”	1 No.	200
17	Hypodermic needles	18,19,20,21 gauge	50 needles of each gauge	300
18	Nylon tube	4 Ø	50 No.	500
19	Ball valve	-	1 No.	300
20	MS sheet	5 kg	5 kg	500
21	Bolts, nuts and miscellaneous	6,8,10 mm	-	1200
Total cost				Rs. 63,050/-
Fabrication cost (40 %)				Rs. 25,220/-
Total cost of machine				Rs. 88,270/-

Appendix - J

COST ECONOMICS OF A VACCUM SEEDER

1. Fixed cost

a. Material cost + Fabrication cost (C) = Rs. 88,270/-

b. Salvage value (S) @10% of total cost machine = Rs. 8,827 /-

2. Operational cost

a. Annual use (U) (Expected operational hours) =1200 h

b. Expected life years (L) = 8 years

a) Fixed cost

i. Depreciation (D)

$$D = \frac{C - S}{UL}$$

$$D = \text{Rs. } 8.28$$

ii. Interest on capital investment @12 % per annum on average price (I)

$$I = \frac{\frac{C + S}{2\,U}}{} \times 0.12 = \text{Rs. } 4.85/\text{ h}$$

iii. Repairs/maintenance cost@ 2 % (R)

$$R = \frac{C}{UL} \times 0.02 = \text{Rs. } 0.18/\text{h}$$

Total fixed cost (D+I+R) = Rs. 13.31/h

3. Operational cost/Variable cost

i. Power consumption = 1.5 kWh
Cost per unit of electricity = Rs. 8
Therefore, cost of electricity = 1.5×8 = Rs. 12/h

ii. Labour cost @Rs. 300 per day (8 hours) per person
or37.5 /- per hour

Total variable cost (P+b) = Rs. 12.00 + Rs. 37.5 = Rs. 49.50

Total cost of operation = Fixed cost +Variable cost

= Rs. (13.31 + 49.50)/h

= Rs. 62.81 / h

1. Cost analysis for seeding one protray by machine

Capacity of the seeder = 100 protrays/h

Therefore, Cost of operation per protray = 62.81/100 = Rs. 0.63/protray

2. Manual operation cost

Labour cost @ Rs. 300 per day (8 hours) per person

or Rs. 37.5 /- per hour

Maximum seeding capacity in protrays – 10 protrays/h

Therefore, Cost of operation per protray =37.5/10 = Rs. 3.75/protray