DEVELOPMENT AND EVALUATION OF FERTILIZER APPLICATION SYSTEM FOR MANGO ORCHARDS

A Thesis submitted to the

Dr. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH

DAPOLI - 415 712, MAHARASHTRA (INDIA)

In the partial fulfillment of the requirements for the degree

of

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)

in

FARM MACHINERY AND POWER

by

KALAMKAR SAINATH BHAGCHAND

B. Tech.(Agril. Engg.)

DEPARTMENT OF FARM MACHINERY AND POWER

COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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Submitted by

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(Regd. No. ENDPM 2019/153)

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OCTOBER, 2021

CANDIDATE'S DECLARATION

I hereby declare that the experimental work and its interpretation of the thesis entitled **"Development and Evaluation of Fertilizer Application System for Mango Orchards"** or part of thereof has not been submitted for any other degree or diploma of any University nor the data have been derived from any thesis/publication of any University or scientific organization. The sources of material used and all assistance received during the course of investigation have been duly acknowledged.

Sainath.k.

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This is to certify that the research project report entitled **"Development and Evaluation of Fertilizer Application System for Mango Orchards"** submitted to the Faculty of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (Maharashtra State) in the partial fulfillment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **FARM MACHINERY AND POWER** embodies the record of a piece of **bonafied** research work carried out by **Mr. Sainath Bhagchand Kalamkar** under my guidance and supervision. No part of the research project report has been submitted for any other degree, diploma or publication in any other form.

The assistance and help received during the course of this project work and sources of the literature have been duly acknowledged.

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**Place : ** CAET, Dapoli

Date 08 **/ OCT / 2021** (Sainath Bhagchand Kalamkar)

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Description
ANOVA	Analysis of Variance
ARDF	ASPEE Agricultural Research and Development Foundation
Avg.	Average
CAET	College of Agricultural Engineering and Technology
Cv.	Cultivar
Dr. B.S.K.K.V.	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth
et al	and others
etc.	et cetera, and other things
Fig.	Figure
GI	Galvanized Iron
H	Hour
HP	Horsepower
Ha	Hectare
i.e.	that is
Kg	Kilogram
km/h	Kilometre per hour
kW	Kilo watt
M	Meter
MT	Millions of tonnes
MS	Mild Steel
m/s	Meter per second
m^3	Cubic meter
Min	Minute
Mm	Millimeter
N	Newton
No.	Number
NS	Non-significant
RSM	Response surface method
S	Second
SWG	Standard Wire Gauge
viz.	Namely

LIST OF SYMBOLS

Symbols	Description
%	Per cent
/	Division
₹	Rupees
˚C	Degree Celsius
º	Degree
+	Plus
=	Equal to
±	Plus-minus
×	Multiplication
≈	Approximately equals to
ø	Diameter
θ	Angle
Π	Pie
δ	Sigma
ρ	Rho
ή	Eta
τ	Tau

ABSTRACT

DEVELOPMENT AND EVALUATION OF FERTILIZER APPLICATION SYSTEM FOR MANGO ORCHARDS

By

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Mango (*Mangifera Indica L.*) is known the world over as a fruit with many nutritional qualities, as it is rich in minerals, fiber, vitamins and provitamins. Mango trees though planted at the same time in an orchard resulted in different sizes of canopy and growth rate. Appropriate nutrient management is one the most important aspect of mango production technology. Dr.B.S.K.K.V., Dapoli recommended dose of fertilizer for a tree age of 10 to 20 years giving fruit yield up to 300 fruits is 50 kg organic manure or 25 kg Vermicompost + 1.5 kg N + 0.5 kg P_2O_5 + 0.5 kg K_2O. The application is done at the onset of monsoon or if irrigation is available immediately after harvest. Traditionally in Konkan region, fertilizer application in mango orchards is done by digging a ring at an equal distance from the center of the trunk and edge of the canopy with pick axe and spade. Due to the unevenness of the application, there is a loss of nutrients from applied fertilizer. Fertilizer ring basin making and fertilizer application is a labouries, drudgery involved work and time-consuming. Due to the small and marginal land holding, four-wheel tractors are either difficult or uneconomical to use. The power weeders are popular and have potential for their use for agricultural operation in Konkan. Till date, not any single machinery was available to apply organic manure and fertilizer in the field which digs the ring below the canopy and applies the fertilizer in the ring. To overcome the above problem, there was a need to develop a suitable fertilizer application system for mango orchards.

Based on agronomic requirement and design consideration on basis of field survey, the power weeder operated fertilizer application system was developed. The developed power-weeder operated fertilizer application system consists of Vermicompost and chemical fertilizer hopper, orifice type metering mechanism for Vermicompost, agitator, slider plate, drive wheel, Power cut-off device, vertical cup feed type fertilizer metering mechanism, furrow opener, ridger and soil covering device. The developed fertilizer application system was tested in the laboratory for the calibration of Vermicompost and fertilizer. The average bulk density and angle of repose for vermicompost was 788.93, 799.30 and 802.07 kg/m^3 and 31.48^0, $32,73^0$ and 30.31^0 at 36.38 %, 42.20 % and 47.05 % moisture content respectively. The physical properties of fertilizer were determined. The average bulk density and angle of repose for Urea and 15:15:15, 16:16:16 and 17:17:17 fertilizer was 1065, 1080, 1115 and 1072 kg/m^3 and 36.08°, 37.87°, 35.43° and 39.34°, respectively.

The field testing of developed power weeder operated fertilizer application system for mango orchards was carried out at the Mango field, ASPEE foundation, Tansa farm, Dist. Palghar. For the operation of the fertilizer application system, a well-tilled loose soil and soil moisture around field capacity is required in field. The power weeder with rotory blades operated 2-3 times around a mango tree. A developed fertilizer application system was attached to the weeder and tested in field at 3/4 and full opening position of the orifice for Vermicompost with three different speeds, three different blades and three different chemical fertilizers for evaluation of field capacity, field efficiency, fuel consumption and depth of ring basin. The 'Design Expert 11' software was used for the analysis. Based on combinations suggested by Design expert software, 17 experiments were carried out at 19.91 and 23.99 % soil moisture each. The results obtained were analyzed by ANOVA to verify the significance of the effect of independent parameters on response parameters.

The field capacity and field efficiency of the fertilizer application system was 0.42, 0.47 and 0.58 ha/h and 52.5, 48.45 and 44.96 % at 1, 1.5 and 2 km/h speeds, respectively. The average fuel consumption for one tree ranged from 0.030 to 0.050 l/tree depends upon the canopy of the tree. The average depth of Vermicompost and fertilizer in the ring with L, C and Hatched type blades were 15.5, 15.4 and 17.7 and 15.2, 14.9 and 16.8 cm at 19.91 and 23.99 % soil moisture content, respectively. The cost of the developed power weeder operated fertilizer application system was Rs. 8727/- and the cost of operation of fertilizer application with the developed fertilizer application system is Rs. 1279 /- ha. It saves 83 % time and 36 % cost as compared to traditional methods. The developed machines found satisfactory for simultaneous application of Vermicompost and fertilizer in ring basin for Mango orchards.
Keywords: fertilizer application system, Vermicompost, chemical fertilizer, field capacity, field efficiency, operating cost

CHAPTER I

INTRODUCTION

Agriculture plays a vital role in India's economy. The shares of the primary sector (including agriculture, forestry, livestock and fishery) are estimated to be 14.4 per cent of the gross value added (GVA) during 2018-19 at current prices (Anonymous, 2018). Mango (*Mangifera Indica L.)* is known the world over as a fruit with many nutritional qualities, as it is rich in minerals, fiber, vitamins and provitamins. Mango is the most important tropical fruit of the world. It can also be grown in subtropical conditions and up to elevations of 1400 meters above the mean sea level. The optimum temperature range for growth is 18 to 35 °C and it can tolerate temperatures as high as 48 °C. It can survive in areas having an average annual rainfall ranging from 250 to 2000 mm. Loamy, alluvial, well-drained, aerated and deep soils rich in organic matter with a pH range of 5.5 to 7.5 are ideal for mango cultivation. India contributes about 64 % of the world's mango production. The production of mango in India is about 18.431 MT from about 2.516 million ha area with a productivity of 7.3 tonnes/ha. In Maharashtra, mango is occupying an area of 4.82 lakh ha with an annual production of 6.33 MT with a productivity of 1.3 tonnes/ha. The productivity of mango in Konkan is about 2.5 to 3.0 tonnes/ha, which is about three times less than the average productivity of the country.

Konkan region is on the west coast of India traditionally known for the commercial cultivation of world-famous Indian mango variety "Alphonso", presently occupying more than 1.8 lakh ha of land area, accounting for nearly 6 % of the total mango area in the country. Alphonso is considered as one of the choicest variety because of its earliness, keeping quality, typical sugar-acid blend, aroma, processing potential. Inspite of this, Alphonso has some inherited drawbacks. Poor mango orchard efficiency (2.5-3.0 t/ha) and high annual fluctuations in mango crop, due to "on" and "off" year of bearing habit, are considered as long-standing constraints in sustainable mango farming in Konkan (Burondkar *et al*., 2018).

Weeding is an important but equally labour intensive agricultural unit operation. Weeding accounts for about 25 % of the total labour requirement (900 - 1200 man-hours/hectare) during a cultivation season (Nag and Dutt, 1979). It is major problem in horticultural crops also. Moreover, the labour requirement for weeding depends on weed flora, weed intensity, time of weeding, and soil moisture at the time of weeding and the efficiency of the worker. Often several weeding operations are necessary to keep the crop weed-free. Weeds compete with crop plants for nutrients and other growth factors and in the absence of an effective control measure, remove 30 to 40 per cent of applied nutrients resulting in significant yield reduction (Dryden and Krishnamurthy, 1977). The most common methods of weed control are mechanical, chemical, biological and traditional methods. Out of these four methods, mechanical weeding either by hand tools or mechanical weeders are most effective. Various types of cutting blades are used for manually operated weeders. V-shaped sweep is preferred where weeders are continuously pushed and tool geometry of these cutting blades is based on soil-tool-plant interaction (Bernacki *et al.,* 1972). Presently, there are many types of weeders available from simple to complex and also motorized weeders.

Mango trees though planted at the same time in an orchard resulted in different sizes of canopy and growth rate. Appropriate nutrient management is one the most important aspect of mango production technology. The inadequate supply of nutrients, as well as overdoses of nutrients, may be harmful to obtaining more yield as well better quality of mango. Application of nutrients should be according to its year yield and canopy size. Hence after the numbering, it is essential to classify trees on following recommended dose for a tree age of 15 to 20 years giving fruit yield up to 300 fruits, nutrient dose recommended is 50 kg organic manure (60 % compost + 40 % fish manure) or 25 kg Vermicompost + 1.5 kg N + 0.5 kg P_2O_5 + 1.0 kg K_2O Potassium should be applied through sulphate of potash (Shinde ***et al.,*** 2006). Based on leaf analysis at every alternate year, need base spraying of Secondary (Ca, Mg, S) and micronutrient ¼ Fe, Mn, Zn, Cu, B½ (50 to 100 g) is also advocated. Application of fertilizer based on the above classes will save input, energy and money. It will also help to stop unwanted vegetative growth. Application of manure/Vermicompost and fertilizer dose should be done as per the recommendation of Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli. An application needs to be done at the onset of monsoon and if irrigation is available immediately after harvest. It is applied by digging a ring at an equal distance from the center of the trunk and edge of the canopy with pick axe and spade. The ring should be 20 cm deep and 30 cm wide. The first bottom layer in the ring should be of manure followed by fertilizers and finally, it should be covered with topsoil. Excess dose of fertilizer leads to vegetative flush even after rains which fail to obtain desirable flowering due to application of Paclobutrazol (Burondkar *et al.*, 2018).

The organic materials are most commonly used to improve soil conditions, fertility and soil organic matter content and to provide micronutrients and other growth factors not normally supplied by inorganic fertilizers. In Konkan, farmers have a low animal population hence the availability of FYM is lower. FYM contains a small percentage of nutrients. It increases the volume of the required fertilizer dose. On average well decomposed farmyard manure contains 0.5 % N, 0.2 % P_2O_5 and 0.5 % K_2O and Vermicompost contains 1.2 % N, 0.5 % P_2O_5 and 1.2 % K_2O. Vermicompost is better than FYM due to its higher nitrogen, phosphorus and potassium content and its ability to improve the soil structure. FYM has low bulk density it increases the volume compared to Vermicompost. Hence for the development of fertilizer application system, we choose Vermicompost as an organic fertilizer.

Till date there is no metering mechanism for the application of FYM/Vermicompost in the field as per scientific recommendation. Therefore, improvements in FYM/Vermicompost application are necessary which can maintain the uniformity of its application. It is also necessary to provide proper mixing or agitating mechanism for the free flow of FYM/Vermicompost which can break the clods. Every year fertilizer is applied by digging a ring by the traditional method. Due to unevenness of the application, there is a loss of nutrients from applied fertilizer. Therefore it is necessary to apply fertilizer in furrow or ridge which can maintain accuracy and precision. It can be quantified the rate of application during the operation and apply uniformly in the field. Uniform distribution and proper placement of fertilizer in the soil have become an increasingly important factor in providing maximum crop response at minimum costs.

The power weeder (Rotory Tiller) is a prime mover in which the direction of travel and its control for field operation is performed by walking behind it. The small power operated cultivator/weeder, power tiller and mini tractor are being popular and used by farmers for various farm operations. There is good potential for their use in agricultural operations like sowing and fertilizer application, field preparations, intercultural in widely spaced row crops, harvesting of cereal crops under upland conditions, transport of farm produce and stationary farm operations. Power weeders are meant for use on small or medium farms where four wheel tractors are either difficult or uneconomical to use. In Konkan, farmers have small land holding capacity because of small or medium farms where four wheel tractors are either difficult or uneconomical to use. Power weeders have good potential for their use for agricultural operation and stationary farm operations in the Konkan region.

In Konkan region, due to heavy rainfall unwanted weeds grow fast in field as well as in orchards. The traditional methods of weed control like hand weeding and manually operated weeders prove to be time consuming and cumbersome in operation with a minimum efficiency. Weeding is the most tedious task of all the labour stages in the farming cycle. Traditionally in Konkan region fertilizer application in mango orchards done by digging a ring at an equal distance from the center of the trunk and edge of the canopy with pick axe and spade. Due to unevenness of the application, there is a loss of nutrients from applied fertilizer. Therefore, it is necessary to apply fertilizer in furrow or ridge which can maintain accuracy and precision. The efficiency of the work is often lowered by hot and humid weather conditions. Fertilizer ring basin making and fertilizer application is a labouries, drudgery involved work and time consuming. Due to the small and marginal land holding four wheel tractors are either difficult or uneconomical to use. Till date not any single machinery was available to apply organic manure and fertilizer in the field which digs the ring below the canopy and applies the fertilizer in the ring. To overcome the above problem, the development of a suitable fertilizer application system is the need of time. Hence to reduce the cost, work stress and drudgery, there arises a need to develop efficient and economic operations of the system of machine which will be effective and efficient.

Hence keeping above points in consideration, the study entitled “Development and evaluation of fertilizer application system for mango orchard” is undertaken with following objectives:

Objectives:

1) To study different methods used for weeding, fertilizer ring basin and fertilizer application system for mango orchards
2) To develop fertilizer application system for mango orchards
3) To evaluate the performance of developed fertilizer application system for mango orchards

CHAPTER II

REVIEW OF LITERATURE

The research work of earlier researchers was reviewed for getting through in site of design of fertilizer applicator, the problem encountered by them and methodologies used. The review made for physical properties of Vermicompost and chemical fertilizer, design, development, testing and economic analysis is presented as below.

2.1 Physical properties of Vermicompost and chemical fertilizer

Agnew *et al.* (2003) measured the air volume and density of compost. The free air space (FAS) and bulk density of manure compost, municipal solid waste compost, and mixtures of bio-solids and amendment materials were measured. These parameters were measured at various moisture contents and compressive loads. They observed that FAS decreased with loading and increasing moisture content whereas wet bulk density increased. FAS and bulk density shows linear relationship for materials taken for study.

Ghazavi *et al.* (2008) reported the results of a series of laboratory experiments performed on three types of sand. For this purpose, a special device has been prepared. The device is well equipped and makes it possible to pour sand from various heights. After pouring sand from a certain height, the angle of repose is measured using the geometry of sand deposition. The results showed that the angle of repose can be correlated to the internal friction of the sand.

Anonymous (2009) studied specifications of commonly used fertilizer. They found that the size of urea fertilizer is 2 - 4 mm IS sieve and for complex fertilizer 15:15:15 and 17:17:17 about 90 % of the material shall pass through 4 mm IS sieve and less than 5 % shall be below 1 mm size.

Valart *et al.* (2012) found that the average values of the angle of wall friction (AWF) or angle of repose of poultry litter on the friction surfaces were in the range of 25 to 39 degree. Increasing the moisture content and particle size decreased the angle of wall friction.

Vanlalmuansangi ***et al.*** (2013) conducted an experiment on the importance of quality testing of locally available Vermicompost based on the standard given by the Fertilizer Control Order. The bulk density of all the samples remains within the standard and ranges between 0.78 to 0.80 g/cm^3. While moisture content is higher in all the samples ranging from 48.71 to 51.46 %, electrical conductivity varied from 1.903 to 5.547 ds/m^{-1} and pH ranged between 5.65 and 6.35. Total organic carbon was between 17.33 to 20.73 % of which sample no. S_2 ranked below the minimum as per FCO specification. The quality of the three samples analyzed was therefore found to be almost the same as that specified by the Fertilizer Control Order with very little short fall in some of the parameters.

Bahram *et al.* (2014) studied the effect of moisture content, particle size and consolidation stress on flow properties of Vermicompost. The results showed significant difference between the flow index values at different stress levels. Greater moisture content and smaller particle size caused poor flowability of Vermicompost. Increasing the moisture content and decreasing the particle size from 1.18 to 0.3 mm, the Vermicompost reduced its flowability from free flowing at moisture content of 25 % (*wb)* to cohesive at moisture content of 35 % (*wb*).

Singh and Singh (2014) studied physical properties of FYM at different moisture content. They found that the bulk density was 292, 510, and 680 kg/m^3 at moisture content of 20.5, 27.2 and 36.4 % (*db*) respectively. The angle of friction with MS sheet was 33˚, 37˚ and 42˚ with increasing moisture content from 20.5 to 36.4 % (*db*).

Zaki *et al.* (2014) studied physical properties of Vermicompost. The moisture content of materials in five levels (10 %, 20 %, 30 %, 40 % and 50 %) and particle size in three levels (0.3, 0.6 and 1.8 mm) were investigated in line with the angle of repose and bulk density. The results showed that the bulk density increased with increasing moisture content and also with decreasing particle size from 0.3 to 1.18 mm, the bulk density increased in the range of 0.60 to 0.80 g/cm^3. The results of the angle of repose indicated that with increasing the particle size, the coefficient of internal friction increases and the angle of repose increased. Particular effects of particle size and moisture content indicated an increase in the mass flow rate with increase in particle size.

Khater (2015) studied physical and chemical properties of compost made of different raw materials. These materials are cattle manure, herbal plants residues and sugar cane plants residues. The bulk density value ranged from 420 to 655 kg/m^3. The moisture content values ranged from 23.50 to 32.10 %. The water holding capacity values ranged from 3.50 to 4.40 g water/g dry. The porosity values ranged from 60.69 to 72.47 % for different compost types. The pH value ranged from 6.3 to 7.8 and EC values ranged from 2.6 to 4.1 dS/m^{-1} for different compost types. The total organic carbon values ranged from 16.6 to 23.89 %. The total organic matter values ranged from 28.60 to 41.20 %. The total nitrogen values ranged from 0.95 to 1.68 %. The total phosphorus and total potassium values ranged from 0.27 to 1.13 % and 0.27 to 2.11 %, respectively, for different compost types. The C/N ratio values ranged from 14.22:1 to 18.52:1.

Anonymous (2016) studied bulk density and sizing of incitec pivot manufactures and imports fertilizers. The size of granular fertilizer ranged between 2-5 mm and bulk density was 800 - 1300 kg/m^3.

Sahu *et al.* (2020) studied physical and frictional properties of farmyard manure (FYM) to develop mechanized application and handling unit of FYM. Application of farmyard manure is not easy due to their variable physical and frictional properties. The physical and frictional properties of FYM were determined at different depths of manure pit *viz.* 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm. The average moisture content, bulk density, dry matter content, angle of repose and angle of friction of FYM at different depths of manure pit were 28.97 per cent *db*, 421.21 kg/m^3, 71.03 per cent, 35˚ and 34˚, respectively.

2.2 Design and development of fertilizer application system

2.2.1. Different methods of weeding, fertilizer ring basin and fertilizer application system

Anonymous (2012) studied time and methods of fertilizer application. The method of application of fertilizer is an essential component of good agricultural practices. The amount and timing of nutrient uptake depends on various factors such as crop variety, planting methods, soil and weather conditions. For optimum crop use efficiency and minimum potentials for environmental pollution, farmers must apply the nutrients near to the times the crop needs them as is practical. When fertilizer is applied by hand, extreme care should be taken to distribute nutrients uniformly and at the exact rates. Where fertilizer application equipment is used, it should be adjusted to ensure uniform spreading at a correct rate. Methods of fertilizer application are broadcasting and placement.

Olaoye *et al***.** (2012) reported that farmers generally expressed their concern for effective weed control measures to arrest the growth and propagation of weeds. The chemical method of weed control was more prominent than manual and mechanical methods. However, its adverse effects on the environment will make the farmers consider and accept mechanical methods of weed control. Manual weeding was the most widely used weed control method but it was labour intensive. The use of a mechanical weeder reduced drudgery and ensures a comfortable posture of the farmer or operator during weeding. This resultantly increased production.

Malhotra and Srivasastava (2015) analyzed the fertilizer requirement of Indian horticulture. The ratio of N:P:K is more tilted towards N in proportion to P or K compared to the greater uptake of K in proportion to P or N by fruits or vegetables, besides no clue whatsoever about the use of micronutrients. These are severe drawbacks in fertilization schedule of horticultural crops, facing today the multitude of nutritional disorders, which remain unattended often in the context of entire productive life of perennial crops. In this background, we attempted to take a stock of the current fertilizer practices being followed in horticulture sector and arrive at some realistic estimate of the fertilizer requirement to dwell upon the policy makers for developing a comprehensive fertilizer use policy in Indian Horticulture.

Anonymous (2016) reported that weed control methods are grouped into cultural, physical, chemical and biological. No single method is successful under all weed situations. Many a time, a combination of these methods gives more effective and economic control than a single method. Mechanical or physical methods of weed control are being employed ever since man began to grow crops. The mechanical methods include tillage, hoeing, hand weeding, digging cheeling, sickling, mowing, burning, flooding, mulching etc. Several cultural practices like tillage, planting, fertilizer application, irrigation etc are employed for creating favorable conditions for the crop. This practice if used properly helps in controlling weeds.

Anonymous (2017) studied fertilizer application methods and compared them. Fertilizer application methods are classified into broadcasting, localized placement (band, hole, half circle), special placement considerations for furrow irrigated soil, Application through the irrigation water and foliar applications. Broadcasting refers to spreading the fertilizer evenly over the soil surface with or without working it into the soil. Localized placement refers to applying fertilizer in a band, hole, or half-circle near the seed row or plants. Banding refers to placing the fertilizer in a continuous narrow strip running parallel to the crop row and fairly close to it. It can also be used on crops with wider in-row spacing, but the half-circle and hole methods may be more convenient. Foliar applications are best suited for applying micronutrients.

Kalaivanan and Saroj (2017) studied weed management in cashew. The productivity of cashew plantations in India is quite low due to many factors including the problem of weeds. Based on the severity of weed infestation the yield reduction was observed as high as 60-70 per cent in some cases. Considerable expenditure was required to keep the plantations weed free. Depending upon the type of weeds and intensity of weed growth, weeding is to be done manually, mechanically or chemically. The weed growth is seen maximum after the monsoon and harvesting becomes a problem if the weeds are not removed. At present, farmers manage weeds in cashew orchards through manual slashing. Other methods for managing weeds in cashew plantations that have been investigated elsewhere include the use of herbicides and intercropping.

Anonymous[1] (2018) studied different fertilizer metering devices and soil covering devices. Different fertilizer metering devices are adjustable opening with agitator disk, adjustable orifice covered with agitator wheel, vertical rotor with spur wheel, vertical rotor with grooves, revolving bottom plate, auger type and covering devices includes drag chain, drag bars, scraper blade, steel press wheel, zero pneumatic press wheel and single and double covering devices.

Manjarekar *et al.* (2018) studied the effect of fertilizer levels on physicochemical parameters and yield of fruits in Mango Cv. Alphonso. They concluded that if proper manuring is done by the growers at the right time, this important crop is saved from deterioration and production can be increased to an appreciable extent. The effect of fertilizer levels on the quality aspect was significant. The manures and fertilizers as per treatments were applied at 1st fortnight of July, in the trenches (30 cm wide and 15 cm deep) which were dug half the distance of the canopy of the tree from its trunk. Farm yard manure 50 kg/tree was commonly applied.

Singh *et al.* (2018) studied principles and methods of fertilizer application in soil. Fertilizers are available in solid granules and are fully soluble or partially soluble. Fertilizers are also available in liquid form. The modes of application solid and liquid fertilizers differ. Solid fertilizers application methods are broadcasting, placement, in-situ operations and foliar application. Ring placement method is mostly practiced for the fruit trees in orchard or for individually grown trees. For ring placement ring like trench of one feet wide and four to six inches deep around the fruit tree with the help of spade corresponding to the circumference of the shoot system of the tree. After digging of ring amount of fertilizers required is calculated separately. Then fertilizer is applied uniformly in the trench. After application fertilizer ring is covered with soil. Till date no any mechanical device is developed for digging ring.

Kaur *et al.* (2019) examined that weeds cause a lot of problems in the crop field. Weeds compete with the main crop for nutrients, water, food, space, sunlight etc. Weeds utilize the nutrients provided to the main crop and sometimes dominate the main crop. Some weeds are very noxious and they are harmful for both humans as well as animals. It is clearly revealed from studies done in field of weeds that use of herbicides used to control weeds cause many effects on soil as it leads to degradation in the quality of soil, water as well as it pollutes environment and also repeated use of same herbicide makes the weeds resistant to that herbicide. Many ways to control weeds like mechanical control, cultural control, chemical control and biological control. But now a day's chemical control is too much widespread in which use of different herbicides done. Over use of chemical fertilizers harms soil health as well as decrease quality of environment. So a new approach called Integrated Weed Management (IWM) came into light in which all the approaches are combine used just to reduce the alone use of herbicides.

2.2.2. Design and development of fertilizer application system and power weeder

Bansal and Leeuwestein (1987) reported the results of experiments conducted to study and factors influencing the metering and distribution pattern of fertilizer from an oscillating trough-type fertilizer applicator. It was observed that the centrality of the raker strip and trough-type mechanism, and symmetry in the angle of oscillation of the latter with respect to the vertical centre line of the hopper are very important to minimize vibrations in the quantity and distribution of fertilizer. With the oscillating-type mechanism, fertilizer falls in a unit distance of travel resulting in a more uniform distribution. The rate of application can be adjusted by varying the angle of oscillation.

Unadi *et al.* (1994) developed 7 row seed cum fertilizer drill with working width of 1.75 m for each row of seed there was seed hopper, a 6 fluted seed metering roller, a double disc furrow opener and for each row a fertilizer metering mechanism.

The fertilizer furrow opener frame was fixed to the seed furrow opener frame to place the fertilizer 2 cm below seed level and 5 cm beside the seed.

Glancey and Adams (1996) designed an applicator for side-dressing row crops with solid organic by-products. Conveying system should capable of metering and distributing the manures in the field. Physical properties of poultry manure must be determined for designing the applicator. They concluded that bulk density of manure was affecting the required input power per unit length of each conveyor.

Kwangwaropas (1999) studied the equipment used for weeding under mango tree. Two types of cultivating machine used for weeding under mango trees were designed and developed. The first type was accomplished by designing some special apparatus to be attached with two kinds of 5 horsepower’s walking type wheel less cultivator. The second type was specially designed and developed walking type wheel less cultivator. The operator gave only slight assistance in controlling the machine to cultivate around a mango tree equipped with C-blade type drum rotors resulted in average weeding efficiency 90.48 %. While 93.31 % weeding efficiency was achieved by the L type blades. A modified locally made walking type cultivator has 76.85 % weeding efficiency. Average working speed around a mango tree in second per round of all types was about 20-30 seconds. Slightly more than one minute was required for each tree in continuous operation. Approximately 50 trees could be finished in an hour. These cultivators were suitable for high soil moisture condition and could work well in soil with 12-22 % moisture content.

Lauge *et al.* (2006) improved the technology available for handling and land application of solid and semi-solid manure products. Further, a prototype precision land applicator was designed and evaluated. They were concluded that a four-auger system was more adopted to handle the manure as compare to scraper type conveyor. Flow rate was influenced by the position of a vertical flow-metering gate and by the speed of the auger.

Tajuddin (2006) developed engine operated blade harrow for weeding. The weeding efficiency of the equipment at 15°, 25° and 35° blade angles, 200, 300, 350 and 450 mm blade widths and 30, 40 and 50 mm depth of operation was recorded. The cost of operation by the power weeder was Rs. 580 per ha. The machine was useful for weeding in between standing row crops like cotton, tapioca and grape. The weeder covers an area of one ha in a day of 8 h. The cost of weeding by this machine comes to only one - third of the weeding cost by manual labourers.

Mankoc *et al.* (2007) studied the flow rate of granular materials through an orifice**.** The flow rate of grains through large orifices is known to be dependent on its diameter to a 5⁄2 power law. This relationship has been checked for big outlet sizes, whereas an empirical fitting parameter is needed to reproduce the behavior for small openings. In this work, they provide experimental data and numerical simulations covering a wide span of outlet sizes, both in three- and two-dimensions. This allows showing that the laws that are usually employed are satisfactory only if a small range of openings is considered. They propose a new law for the mass flow rate of grains that correctly reproduces the data for all the orifice sizes, including the behaviors for very large and very small outlet sizes.

Singh and Vatsa (2007) developed a light weight power tiller operated seed drill for hilly region. The machine was consisted of a main frame, ground wheels, seed and fertilizer boxes, furrow opener, power transmission system and hitch. The metering of seeds and fertilizers was accomplished with fluted rollers. The metering shaft was driven by the chain and sprocket from the ground wheel. The total weigh of the machine was 27 kg. The depth of sowing was adjusted by lowering and raising the furrow openers. The machine was easily attached to the power tiller by a bolt. Hopper capacity of seed and fertilizer was 3 kg and 3.5 kg respectively.

Verma and Dewangan (2007) designed and developed furrow openers for seed cum fertilizer drill. The study was conducted on the basis of penetration ability of furrow openers, non clogging of seed and fertilizer in boots, on the amount of soil disturbance and draft. It was reported that the shoe type furrow openers gives the best performance. The draft force of shoe type furrow opener was low because of its lower boot width and better design of soil working parts. They conclude that the draft force was directly proportional to the depth of operation and draft force increases with 0.40-0.45 kgf/cm depth of operation. Soil disturbance was less due to smaller boot width.

Chase (2010) reported that hoppers are must be designed as they are easy to load used in industry for protection and storage of powder materials. Design of hopper affects the rate of flow of the powder. He reported the issues related to designing of hopper at the time of discharge or their mixing with solid/ dead space that reduces the effective holding capacity of the hopper.

Mandal and Thakur (2010) developed subsoiler-cum-differential rate fertilizer applicator. The equipment consisted of a rectangular frame, a main winged tine, two shallow leading winged tines, a depth control device, a fertilizer box of 100 kg capacity, positive feed type fertilizer metering devices and a ground wheel with chain and sprockets for transmitting power to the metering mechanism. The equipment had the option to place fertilizers up to a 500-mm soil depth by the main winged tine and delivering fertilizer up to 250-mm deep using the leading tines, thereby helping to place fertilizer at different depths in vertical soil profile in a single pass. All three tines had independent metering systems. Options were provided to meter and deliver either 33.3 % or 25.0 % or 20.0 % of the total recommended fertilizers with the main tine and the remaining amount through two shallow leading tines.

Raghvendra *et al.* (2013) developed and evaluated ridge planter for cotton. Cotton planting is conventionally done by manual dibbling which involves extensive labours compared to other operations, this result in higher cost of cultivation and delay in planting during planting season where available soil moisture is crucial in the northern Karnataka region. The crop, machine and operational parameters were identified and selected and the tractor operated ridge planter was developed and evaluated for its performance in actual field conditions. The forward speed of operation was optimized as 1.25 m/s, considering seed rate and seed spacing. The average draft and fuel consumption of the planter were 2300 N and 3.83 l/hr, respectively. The field capacity of the planter was 0.89 ha/hr with field efficiency of 73.55 per cent. The cost of operation of ridge planter for sowing cotton was found to be 433 Rs/ha compared to 1013 Rs/ha for conventional method.

Reddy *et al.* (2013) developed animal operated farm yard manure applicator. It consists of different components *viz.*, bullock cart chassis and frame, main axle shaft, steel wheels with rubber padding, agitator, manure box, sliding plate and power transmission system. A pair of bullock acts as power sources for hauling purposes. Power is transmitted by 1:3 ratio of power reduction (main axle shaft: agitator shaft). The animal walking speed is mainly decided to the power transmission of manure applicator because agitator rotation is directly related to the main axle shaft.

Jadhav (2014) developed power tiller operated three row dry paddy seed cum fertilizer drill. The drive wheel was made up of mild steel flat of 45 mm × 5 mm with the diameter of lugged wheel taken as 0.43 m. The hopper of seed and fertilizer were trapezoidal and half trapezoidal respectively. The angle of inclination of seed and fertilizer with vertical was 30˚. The location of seed cum fertilizer hopper was 45 cm above the ground and row to row spacing was 0.2 m. Seed metering mechanism was cup feed type. The cell depth was c=2 mm for 5-7 seeds were picked up by each cup.

The edge shaped feed metering mechanism was placed in secondary fertilizer hopper. The power from ground wheel to fertilizer metering shaft was taken by chain and sprocket. Shoe type furrow openers were used as uniform depth of sowing was required. The rack angle was 33° in order to make cut the soil 3 to 5 cm deep. Polythene tubes of 25 mm diameter and 2 mm thick were used to convey seed from orifice to furrow opener by gravity. The frame of 3 row seed cum fertilizer drill was made of mild steel square pipe of 25 × 25 × 5 mm with square cross section. Provision was made to adjust the spacing between two furrow openers. The seed drill was operated at three different speed of operation 1.54, 1.69, and 1.89 km/h. The 1.89 km/h speed gave desired results. In 1.89 km/h operating speed, seed rate as well as seed spacing, was properly maintained as per requirement. So, 1.89 km/h speed was selected for sowing operation and gives better results than the other operating speeds.

Thorat *et al.* *(*2014) develop ridge profile power weeder for ridge planted crops. The main working components of the weeder were cutting blades and rotor shaft. Three types of blades (L-type, C-type and Flat-type) were selected having length, width and thickness of 100 mm, 25 mm and 6 mm, respectively, operating with a rotor shaft of 18 mm in diameter. C-type blades were most suitable at gang speed of 200 rpm and 15.26±0.96 % (*d*b) soil moisture content with weeding efficiency, plant damage, field capacity of 91.37 %, 2.66 % and 0.086 ha/h, respectively. Time saving with ridge profile power weeder as compared to manual weeding was 92.97 %.

Jain and Lawrance (2015) designed and developed a bullock-drawn farmyard manure spreader. The developed machine was designed to apply FYM uniformly. The desired application rate was also considered in the field. The spreader was evaluated at four widths of the delivery slot of manure box (50-200 mm). They observed that the application rate increased with an increase in the area of the opening of the delivery slots.

Patil and Dhande (2015) developed the bullock-drawn dry paddy seed cum fertilizer drill for upland cultivation. Based on the physical characteristics of seed, development of dry paddy seed cum fertilizer drill was done. The seed and fertilizer box was made trapezoidal for free flow of seeds and fertilizer without bridging. The cup feed mechanism was selected for metering paddy seeds to avoid seed damage and hence does not affect germination. For fertilizer metering, an adjustable orifice type mechanism was provided. A clutch is provided for disengaging power to the metering mechanism during turning. For seed and fertilizer placement, shoe and shovel type of furrow openers were used. A provision was made to adjust the row to row spacing as per requirement. The average theoretical field capacity, effective field capacity and field efficiency were 0.151 ha/h, 0.11 ha/h and 75.96 %, respectively.

Paul (2015) describes methods to measure flow rate and jamming onset of granules discharged through a flat-bottom cylindrical hopper with a circular orifice. The intrinsic jamming onset for ideal particles (spherical, monodisperse, smooth) was experimentally measured by two independent methods, with good agreement. For non-ideal particles, the normalized jamming onset increases with elongated granule shape broadened size distribution and increased friction as measured by the drained angle of repose. An empirical model of the jamming onset is introduced to quantify these effects over the range of materials investigated. The jamming onset can be used as a measure of differentiation between relatively free-owing granules.

Anisa and Geeta (2017) design and developed the rotary paddy weeder with different angles of blade and its performance was compared with conventional manual weeding. Six serrated blades were fixed on bush drum, shaft of diameter 2.5 cm with axle of 1.1 cm diameter. The blades were fixed with three different angles on the bush drum in different weeder, was 10º, 15º and straight. The weeder with straight blade angle (900) gave highest weeding efficiency than the blades with angle of 100 and 150.

Kumar *et al.* (2017) designed and developed groundnut planter for power weeder. The basic idea for mounting of groundnut planter to the power weeder is "the negative draft generation of the power weeder helps to reduce the positive draft requirement of groundnut planter". The row to row spacing was also measured at different locations; it was observed that 30 cm spacing between two rows throughout the field. The depth and width of furrow opener were measured under field condition. It was observed that, the average width and depth of furrow opener were 10 cm and 5 cm respectively for entire row. Developed power weeder drawn groundnut planter consists of one ground wheel of diameter 38.12 cm, three no. of plates provided mounted on the rotating shaft. The entire attachment was fixed on the frame. Ground wheel rotates the power transmit with the suitable gears and chain and rotate metering unit (3 plates) with attached spoons. The total length of the machine 1.2 m and width is 90 cm.

Selvakumar *et al*. (2017) design and fabricated the manually operated double wheel weeder for crop which had a gap of 5-10 inches between the plants. The power from the man was transmitted from wheel shaft to sprocket which was fixed to the shaft with the help of bushes. Then the chain sprocket mechanism was going to actuate and power was transmitted to the shaft. Shaft rotated the two wheels mounted on the bearings and fixed by wheel hubs. Vehicle moved in a forward direction and the blades entered into the soil between rows of crops and removed then weeds.

Sehsah (2018) developed prototype swing mechanical arm weeder for weed control of orchard trees. The swing mechanical arm was constructed from steel, ground wheel carried the arm. The DC Electric motor with 12 V was used as the source of power to operate the rotary blades weeder. Three rotational speeds 1600 rpm, 2200 rpm and 2600 rpm were adjusted and controlled by the short resistor circuit. The prototype electric weeder was evaluated under three forward speeds 3.2 kmh^{-1}, 4.1 kmh^{-1} and 5.7 kmh^{-1} at three rotational speeds 1600 rpm, 2200 rpm and 2600 rpm for weeder and two different blades. The electric weeder with controlled swing mechanical arm may be applied to control of the weeds in citrus orchards tree field. The rotational speed 2600 rpm and forward speed 3.2 kmh^{-1} gave the maximum weeding efficiency under orange orchards tree field conditions. The blades weeder was more effective in controlling weeds than the tynes. The developed electric weeder may be ideal for weeding under orchard trees.

Sirmour *et al.* (2018) evaluated the performance of weeder with power of 2 hp, 2-stroke petrol engine, compact and light in weight, self propelled with durable floating system. It was centrally driven with worm gear box for transmission and working width of the developed machine was adjusted between 140 mm to 250 mm. It was also equipped with rotating blades having 176 rpm and was centrally driven. Due to compactness and low weight it was easily maneuverable. Different types of rotors were designed with 4, 6 and 8 blades. The power transmission from the engine to the rotor was done by means of a flexible shaft.

Sahu[1] *et al.* (2020) developed tractor drawn FYM applicator cum planter. They provided nine orifice openings for FYM delivery at bottom surface of hopper. A counter shaft was fixed which takes drive from ground wheel and rotates agitator. An agitator type feeding mechanism for FYM and inclined metering unit for seeds was provided. The FYM metering mechanism has speed reduction from main axle shaft to agitator shaft been 1:0.6 ratios. The FYM agitating shaft had 28, 33 and 49 RPM at tractor forward speed of 2, 4 and 6 km/h, respectively. These speeds were sufficient to break the clod of FYM.

2.2.3 Performance of developed fertilizer application system and power weeder

Unadi and Gupta (1994) evaluated the performance of 7 row seed cum fertilizer drill. The capacity of machine was about 0.3 ha/h at the forward speed 0.7 m/sec and field efficiency of 72.2 per cent. Damage due the metering mechanism was nil for the dry paddy and 0.6 per cent of soaked paddy.

Singh and Vatsa (2007) evaluated the performance of a light weight power tiller operated seed drill for hilly region. The machine performance parameters like effective field capacity, field efficiency, speed of operation, fuel consumption, depth of sowing and labor requirement were determined. For comparing the performance of the drill with the farmer’s field, a minimum plot size of 10× 8 m^2 was taken with three replications for both methods. The operating speed of the machine was 2.1 km/h. The actual seed and fertilizer rates with the machine were 126 and 276 kg/ha, which was lower than the broadcasting method. The effective field capacity was 0.09 ha/h and 0.02 ha/h with the seed drill and traditional method respectively. The labor requirement was only 22 man-h/ha with the seed drill as compared to 100 man-h/ha with the traditional method, which was 78 %. The cost of sowing with the seed drill was Rs. 922 /ha as compared to Rs. 2438 /ha with the traditional method, resulting in net savings of Rs. 1516 /ha (68.18 %).

Mandal and Thakur (2010) evaluated subsoiler-cum-differential rate fertilizer applicator. The equipment consisted of a rectangular frame, a main winged tine, two shallow leading winged tines, a depth control device, a fertilizer box of 100 kg capacity, positive feed type fertilizer metering devices and a ground wheel with chain and sprockets for transmitting power to the metering mechanism. The equipment had the option to place fertilizers up to a 500-mm soil depth by the main winged tine and delivering fertilizer up to 250-mm deep using the leading tines, thereby helping to place fertilizer at different depths in vertical soil profile in a single pass. All three tines had independent metering systems. Options were provided to meter and deliver either 33.3 % or 25.0 % or 20.0 % of the total recommended fertilizers with the main tine and the remaining amount through two shallow leading tines. The laboratory evaluations indicated a coefficient of uniformity of more than 90 % for application rates of 250, 500, 750 and 1000 kg/ha. The equipment was tested in the field to observe its performance on sugarcane with results showing an increase of 16.2, 16.4

and 35.4 % in yield as compared to conventional ploughing with in-furrow fertilizer application (Control). Subsoiling alone increased the cane weight, number of millable cane and cane yield by 4.3, 11.4 and 15.9 % compared to the control.

Srinivas *et al*. (2010) studied comparative performance of different power weeders in rainfed sweet sorghum crop. Three commercially available power weeders were evaluated for weeding and inter-cultivation in sweet sorghum crop in Andhra Pradesh.The weeding efficiency of 'L' shape blade power weeder was found to be 91 % where as 'C' type and sweep type blade weeder recorded 87 % and 84 % respectively. The performance index of 'L' shape, Sweep shape and 'C' type blade weeder were observed to be 169.84, 153.23 and 114.30 respectively. Field capacity of Sweep type weeder was 0.12 ha/h which is more than 'C' and 'L' type blade weeder and plant damage observed minimum as compared to other two. The cost of operation for Sweep blade power weeder was Rs.550 against Rs. 580 and Rs. 429 per hectare for 'C' and 'L' shape blade power weeder. It is economical and more effective to use L-shape weeder as it saved 10.88 % weeding cost; reduce plant damage and achieved weeding efficiency 84 per cent.

Kumar and Thakur (2011) studied evaluation of deep soil volume loosener-cum-fertilizer. Deep soil volume loosening unit consisted of a pair of specially designed V-shaped tines mounted on a rectangular frame and positioned exactly behind the tractor rear wheels. The V-shaped tines could deform the soil and place it at almost same location without inversion, thereby maintaining original level of the field after soil loosening. The fertilizer placement unit consisted of two fertilizers boxes, each of 75 kg capacity with independent metering system and a ground drive wheel for power transmission. Metered quantity of fertilizer (250 to 1000 kg/ha) could be placed in soil with four inverted-T openers with attachment for fertilizer conveying. Two floating armed spiked roller clod crushing units were positioned behind each V-shaped tine for soil pulverization and consolidation of tilled soil for moisture conservation. Laboratory and field evaluations indicated that the developed equipment performed its intended functions with coefficient of uniformity of more than 94% for fertilizer application rates up to 1,000 kg/ha^{-1}. The equipment was designed for performing general tillage in laser leveled fields, but can be used in row crop cultivation, especially for sugarcane ratoon management, as it could perform all the desired operations in a single pass.

Gavali and Kulkarni (2014) conducted a comparative study for portable weeders and power tillers in the Indian market. Various methods used for weeds removal and various equipments used in mechanical weed removal were discussed. The study revealed that most of the Indian farmers, majority of which was small scale farmers could afford only portable weeders. These small scale farmers as such do not use mechanical weed control methods. Chemical and manual weeding was predominantly used by these small scale farmers. The literature survey indicated that portable weeders were relatively less expensive in operation and maintenance but were also less versatile. Power tillers were considerably more expensive but were also much more versatile and could be operated in variable soil conditions.

Kumar *et al.* (2014) studied different types of weeding blades for weed removal. The size and shape of the blades affected the weeding efficiency. It was observed that L-type blade recorded higher weeding efficiency (91 per cent) when compared to I-type and C-type blades. Whereas, the I-type blades consumed less power (0.65 hp) when compared to L-type and C type blade.

Batta *et al.* (2015) developed and evaluated tractor operated manure spreader with rear vertical roller. The moisture content of manure used for the operation varied from 30-40 % (*wb*) and its density varied from 430-480 kg/m^3. The machine loading capacity varied from 1.0-1.2 tonnes. The machine was operated at different forward speeds between 2.0 to7.0 kmph and at 1400, 1500 and 1600 engine rpm. The machine mean swath width varied from 2.3-4.0 m, mean field capacity varied from 0.11 to 0.55 ha/h and mean fuel consumption varied from 5.35-7.80 l/h. The manure mean application rate during field experiments varied between 10.58-36.37 t/ha. The average saving in time for spreading manure with tractor operated manure spreader was 66.17 % and average saving of cost was 50.43 % as compared to traditional trolley method. Increasing of engine rpm and forward speed of tractor combined resulted in increase in field capacity of machine, increase in fuel consumption and decrease in manure application rate per unit area.

Kumar *et al.* (2015) developed and evaluated animal drawn maize ridger. Ridging of maize crop 30 DAS is a very important operation and maize ridging is conventionally done by manually which involves extensive labors compared to other operations, this result in higher cost of cultivation and required higher drudgery. The crop, machine and operational parameters were identified and selected and the animal drawn maize ridger was developed and evaluated for its performance in actual field conditions. The ridge dimensions were optimized top width, bottom width and ridge height (9.14 cm, 16.72 cm, 43.5 cm) with total volume of soil cover 425.37 cm^3 considering plant height and row to row spacing. The average draft of the ridger 69.81 kg-f was observed during ridging operation. The field capacity of the maize ridger was 0.06 ha/h with field efficiency of 74.46 per cent. The cost of operation of maize ridger for ridging maize was found to be 1737.79 Rs/ha.

Anisa and Geeta (2017) studied performance of the rotory weeder with different angle blades. The cost of weeding can be substantially reduce by introducing improve weeding tools. Six serrated blades were fixed on bush drum, shaft of diameter 2.5 cm with axle of 1.1 cm diameter. The blades was fixed with three different angels on the bush drum in different weeder, was 10º, 15º and straight. Its performance was compared with conventional manual weeding. Using it in wet field conditions, the field capacity of 80 to 85 per cent during the operation, it was found that weeder with straight blade angles gave highest weeding efficiency other than two weeding methods.

Choudhary *et al.* (2017) developed bioslurry-cum-FYM applicator. An applicator, the subject of this report designed manually operated Bioslurry-cum-FYM applicator for spreading bioslurry and FYM on the field. The overall length, width and height of the machine were taken as per ergonomic design consideration. The application rate of bioslurry and FYM was determined at $1/3^{rd}$, $2/3^{rd}$ and full opening. The theoretical application rate of bioslurry at respective opening was 1.288 t/ha, 2.252 t/ha and 3.085 t/ha and of FYM was 1.039 t/ha, 1.455 t/ha and 2.501 t/ha, respectively. It was observed that the application width of bioslurry at 2/3 of opening was 102.6 cm with a minimum SD and CV of 6.189 cm and 6.032 %, respectively. The width of application of FYM at 2/3 of opening was 119.8 cm with minimum SD and CV of 2.775 cm and 2.316 %, respectively.

Sahu and Goel (2017) evaluated the performance of power weeder having three types of blade which were fitted with the weeder and its performance was measured. The highest weeding efficiency of hatched type blade was found to be 84.30 % in wet land and 82.280 % in dry land, whereas the same for L-type blade and C type blade weeders were 72.83 % and 62.79 % in wet land and 71.03 % and 63.67 % in dry land at a soil moisture content of 14.5 % respectively. The performance index of hatched shape, L shape and C shape blade weeder were observed to be 186.49, 117.70 and 125.15 in wet land and 190.81, 148.16 and 126.47 in dry land at

14.5 % moisture content respectively. At the same moisture content i.e. 14.5 %, the highest plant damage of 11.60 % was observed with L type blades while the lowest plant damage of 4.0 % was observed with hatchet type blade. The cost of operation for the developed weeder was found to be Rs 177.10 /h and Rs 4997 /ha.

Mandloi *et al*. (2018) developed mini tractor drawn semiautomatic two row planter cum fertilizer applicator. The potato planter places potato tubers and fertilizer simultaneously at appropriate depth and the cost of operation of the planter was 1562 Rs/ha which is almost half (3285 Rs/ha) compared to medium sized tractor operated planter.

Singh and Thakur (2018) studied laboratory and field evaluation of subsoiler-cum Vermicompost and soil amendments applicator. A tractor drawn ‘subsoiler cum Vermicompost and soil amendments applicator’ was design and developed to examine the basic concept for placement of organic manures and inorganic fertilizers in subsoil at different depth up to 400 mm. The developed machine was evaluated in laboratory for discharge rate and distribution pattern of different organic manures *viz.,* Vermicompost, pressmud and FYM at three moisture states and soil amendments *i.e.* gypsum, lime, cement and rice husk. Prior to laboratory testing of the machine, the physical properties of materials were studied. The machine was also tested under field condition on the basis of changes in dry bulk density, specific draft and wheel slippage at 250, 300, 350 and 400 mm depths of operation. The results revealed that the bulk density was uniform throughout the soil profile after operating at 400 mm depth. The bulk density reduced to a maximum of 13.88 per cent. The specific draft for 400 mm depth of operation was found lower by 33.26 per cent than that at 250 mm depth**.** Whereas, the wheel slippage was found to a maximum of 21.07 per cent at the draft of 12.20 kN for 400 mm depth of operation. The results obtained during performance evaluation of developed machine on response of mustard crop have clearly revealed the advantage of subsoiling and deep placement of organic and inorganic fertilizers in terms of substantial increase in yield parameters.

Singh *et al.* (2018) studied performance of furrow opener for sugarcane. The research was conducted to evaluate the effects of different types of furrow opener, depth and speed of operation on soil properties, draft force, soil disturbance and germination percentage and to select the best furrow openers for establishment of sugarcane crop. The experiment was conducted on a silt loam textured soil using three furrow openers *viz.* IISR furrower, IISR deep furrower and conventional type ridger operated at three average speeds of 0.96, 1.46 and 3.7 km/h and three depths of furrows 100, 150 and 250 mm. The parameters like draft force, soil penetration resistance, ridge height, volume of soil disturbed and germination percentage were determined. Soil penetration resistance decreased with increase operational speeds of each furrow opener's type and increased with increase in depth of furrow. Soil disturbance characteristics and draft force requirements increased with increases in the speeds and depth of operation.

A large amount of information about FYM, Vermicompost and chemical fertilizer can be found in the scientific literature. The moisture content, bulk density, volume and angle of repose are important physical properties required for designing of fertilizer boxes and fertilizer metering mechanisms. The trapezoidal shape of fertilizer hopper for free flow of Vermicompost and fertilizer without bridging was used by previous researchers. The FYM/Vermicompost rate of mango was 50 and 25 kg/tree and fertilizer rate is 5-5.5 kg/tree. The operating speed of power weeder is 1 to 3 km/h. The shovel type furrow opener gives uniform depth of sowing with minimum disturbance to avoid mixing the top dry soil with the underlying moist soil at level. Also clutch was used on fertilizer metering mechanism for disengagement of power during transportation and moving from one tree to another tree. Roller type metering mechanism gives uniform application of fertilizer during operations. For covering the ring soil covering device was used. The angle of inclination of the drill tube to vertical should not exceed 25˚. Organic fertilizer in the fields needs uniform application in ring form into the soil surface at predetermined depths. After reviewing the above literature not any single machinery was available to apply the fertilizer in the ring. Therefore, it is important to work on the design and development of fertilizer and organic manure applications systems for mango orchards. To complete the tasks it is important to work on physical properties, design parameters for developing and testing in a laboratory as well as field for mango orchards. The above findings were useful for development of power weeder operated fertilizer application system for mango orchards. These are presented and discussed in materials and methods.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods employed for different methods of weeding, fertilizer ring basin and fertilizer application system, physical characteristics of Vermicompost and chemical fertilizer, design, development, laboratory testing, field testing and cost economics of applicator in details. Rotory power weeder drawn fertilizer applicator was designed in solid works (AutoCAD), fabricated and tested at ASPEE Agricultural Research and Development Foundation, Tansa farm, Dist. Palghar. To complete the tasks of research work standard methods has been used and presented on the following headings:

3.1 Study of different methods of weeding, fertilizer ring basin and fertilizer application system

3.2 Physical properties of Vermicompost and soil

3.3 Design considerations

3.4 Development of fertilizer application system

3.5 Performance evaluation of developed fertilizer application system

3.1 Study of different methods of weeding, fertilizer ring basin and fertilizer application system

To complete the research task and to know exact requirements of mango farmers, a field survey was carried out of 10 mango farms in Dapoli to know different methods adopted by farmers for weeding, fertilizer application and fertilizer ring making for mango orchards, plant characteristics, planting methods, cost economics, time and labour requirement for application of fertilizer. The questionnaires was prepared to collect the information from the farmers and format of questionnaires are presented in Appendix-A and cultural practices adopted by Mango growing farmers for weeding, fertilizer ring making and fertilizer application are presented in Appendix-B.

From the survey, study was carried out of different methods of weeding, fertilizer ring basin and fertilizer application system.

i) Different methods of weeding
ii) Different methods of making fertilizer ring basin
iii) Different methods of fertilizer application

3.1.1 Different methods of weeding

The main objectives of weed control are to improve the soil condition by reducing evaporation from the soil surface, infiltration of rain or surface water and reduce runoff.

3.1.1.1 Manual methods:

Manual methods like hand pulling and sickling are used by some farmers for weed control. Hand pulling is most efficient in annual and biennial weeds. Sickling is done to remove the tall growth of perennial weeds and to cut at the ground level. Sickle weeding is the most common method of weed control adopted by farmers in orchards. From the survey, we observed that manual weeding is very effective against annuals, biennials and controls only upper portions of perennial weeds. Manual methods of weeding are safe and do not require any involve any skill. It is possible in near plants but takes a longer period of time to complete the task, labour consuming and requires ideal and optimum specific conditions for operations.

3.1.1.2 Mechanical methods:

The mechanical method of weeding by using brush cutter or tractors and tillers with special weeding tools attachments are used by farmers for weed control. Tillage practices like ploughing and mowing are used to clear off weeds, especially in newly established orchards where sufficient spaces may be available for inter-cultivation. It is observed that the type and nature of tools used in the mechanical methods depend upon the row spacing adopted for the orchards. However, in Konkan due to undulating topography in orchards are grown, mechanical weeding is difficult. In this situation, tractor-driven weed cutters can’t work. The motorized weed cutters, brush cutters and power weeders are used by farmers to control weed in mango orchards. Mechanical weeding is efficient and economical compared to manual weeding and covered a large area in a shorter time but perennial and problematic weeds cannot be controlled. The possibility of damaging crops in mechanical methods is more.

3.1.1.3 Any other methods:

Cover cropping is another practice used in mango orchards to control the growth of weeds, some farmers growing green manure crops like dhaincha in between two rows. Herbicides have been used to some extent by farmers in mango orchards to control weeds. *Dalapon* is used by farmers for controlling dicot and monocot weeds in mango orchards. Herbicides helped to considerably reduce the recurrence of weeds and cost of weed control in chemical methods is lowest among all methods. Herbicides are hazardous to environments. Excessive uses of herbicides reduce organic matter of soil; decrease water holding capacity and reduce fertility.

From the survey, it is observed that every method of weed control has its own advantages and disadvantages. No single method is successful under all weed situations. Many a time, a combination of these methods gives more effective and economic control than a single method.

3.1.2 Different methods of making fertilizer ring basin

3.1.2.1 Manual methods:

In manual methods, farmers dig the ring at an equal distance from the center of the trunk and edge of the canopy with pick axe and spade and apply the fertilizer in the ring manually. In manual methods digging is possible near plants for the newly planted orchards and does not require any skill. Whereas it takes a longer period of time to complete the task and requires ideal and optimum specific conditions for operation.

3.1.2.2 Mechanical methods:

Till date, not any single machinery was available to dig the ring furrow below canopy and apply the fertilizer in the ring.

3.1.3 Different methods of fertilizer application

The method of application of fertilizer (organic and inorganic) is an essential component of good agricultural practices. For good agricultural practices, the farmer chooses the timing and quantity in such a way that as much as possible of the nutrients is used by the plants.

3.1.3.1 Placement:

Ring placement or circular placement method is mostly adopted by farmers for mango orchards. In this method, farmers apply organic manures and fertilizer around the trunk of fruit trees in the active zone. In ring placement fixation of nutrients is greatly reduced and utilization of fertilizers by the plants is higher but it requires more costly equipment for application. It is difficult to use in high-density population orchards.

3.1.3. 2 Localized placements:

Localized placement is used by farmers for the application of fertilizer close to the plants in bands or in pockets. Generally, Paclobutrazol is applied in localized placements. It reduces the fixation of phosphorous and potassium fertilizer and provide adequate nutrients to young plants. It requires specialized equipment for applications

From the survey, it is observed that in Konkan region average canopy diameter of mango tree was 6-8 m and average trunk height was 1.27 m. This trunk height is sufficient to work with power weeder in below canopy of mango orchards. In mango orchards, fertilizer was applied in the trenches (30 cm wide and 15 cm deep) which were dug half the distance of the canopy of the tree from its trunk. The average ring diameter (50 %) of canopy was observed as 4.4 m. From these, we estimate the average periphery of the ring basin. The average periphery of the ring basin is observed as 12 m. The labour required for fertilizer application in mango orchards was 10 man days/ha.

3.2 Physical properties of Vermicompost and soil

3.2.1Physical properties of Vermicompost

3.2.1.1 Moisture content

The moisture content of Vermicompost was determined by oven drying method. The Vermicompost sample is weighed with crucible and placed in the oven at 55^{o}C for 24 hours (Choudhary *et al.*, 2017). The oven was set at a temperature of 55±1^{o}C. Firstly, the empty sample box weight was measured (W_1). Then, the weight of sample box with Vermicompost was measured (W_2). The desired temperature of 55±1^{o}C was set the sample was kept in the oven. After 24 hours, the box with lid was taken out from the oven and put into desiccators for 10-15 minutes and then the weight of sample with box was measured (W_3). The moisture content was calculated by using the Equation 3.1 (Sahu *et al.,* 2020). The observations are presented in Appendix- C.

$$\text{Moisture content \% (w.b.)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100 \qquad \text{…. (3.1)}$$

Where,

W_1 = Weight of sample box, g;

W_2 = Weight of sample box with Vermicompost before drying, g;

W_3 = Weight of sample box with Vermicompost after oven drying, g.

3.2.1.2 Bulk Density

Bulk density or moist density is the total mass of the sample per unit of its total volume. Bulk density is important parameters to design hopper and other storage structure. Bulk density is considered to determine the capacity of hopper. Bulk density affects handling of Vermicompost in the hopper. Bulk density influences the volume requirement of the hopper. The bulk density of sample was determined by placing the sample of Vermicompost in a cylinder container then weighed by using electronic balance with least count of 1g. A container of 1000 ml was taken and filled with Vermicompost and then the weight (W_t) of 1000 ml Vermicompost in kg was recorded. The bulk density was calculated by using Equation 3.2 (Sahu *et al.*, 2020). The observations are presented in Appendix-C.

$$(\rho) = \frac{W}{L \times \frac{\pi d^2}{4}} \quad \text{…. (3.2)}$$

Where,

ρ = Bulk density, g/cm^3

W= Weight of sample, g

L = Length of cylinder (cm)

d = Diameter of cylinder (cm).

3.2.1.3 Angle of repose

Angle of repose is a term used to describe the maximum angle, measured upwards from horizontal, at which a pile of a particular material will remain stable without any of the material sliding downward. It is useful to designing the storage and transportation machinery for granular materials. It was calculated by pouring the Vermicompost from the conical shape funnel from height of 50 cm on plate of 60 cm. After the material get settled the height of the cone was measured. The angle of repose was therefore determined from Equation. 3.3 (Sahu *et al.*, 2020). The observations are presented in Appendix-C.

$$\theta = \tan^{-1}\left(\frac{H}{R}\right) \quad \text{…. (3.3)}$$

Where,

H = Height of heap, cm;

R = Radius of the heap, cm.

3.2.2 Soil Parameters

The soil parameters of experimental plot were taken into considerations as discussed below.

3.2.2.1 Types of soil

The types of soil of test plot was black sticky. The type of soil can decide the suitability of soil for a particular crop, it also helpful to decide the nutrient demand of crop for that kind of soil. It also affect on the performance of the machine.

3.2.2.2 Moisture content of soil

Moisture content of soil was calculated by oven drying method. The sample was weighted with crucible and placed in the oven at 105^{o}C for 24 hours (Reddy and Dronachari, 2014). The sample was weighted by electronic balance on its least count of 1g. The observations are presented in Appendix- D.

3.2.2.3 Bulk density of soil

The bulk density of soil was determined by placing the sample of soil in a cylinder container then weighed by using electronic balance with least count of 1g. A container of 1000 ml was taken and filled with soil and then the weight (W_t) of 1000 ml soil in kg was recorded. The observations are presented in Appendix-D.

3.3 Design Considerations

A power weeder-drawn fertilizer application system with a facility of applying Vermicompost and complex chemical fertilizer simultaneously is to be designed in this study for accurate application rate of Vermicompost and uniform application of chemical fertilizer during field operation in the ridge and covering the surface of the field. The design of machine components was based on the principles of operations, tested and compared with the conventional method. The mechanical design details were also given with due attention so, as to give adequate functional rigidity for the design of the machine.

3.3.1 Agronomic requirement

The agronomic requirements are important for applying fertilizer. The principle of sowing and planting operations are followed for the development of fertilizer application system. The agronomic requirements of fertilizer application system based on recommendations and results of survey for adopted method are as follows:

1. In mango orchards fertilizer are applied in the trenches (30 cm wide and 15 cm deep) which are dug half the distance of the canopy of the tree from its trunk.
2. The recommended dose of fertilizer for mango orchards are 50 kg FYM or 25 kg Vermicompost and 1.5 kg N, 0.5 kg P_2O_5 and 0.5 kg K_2O.

3. Average canopy diameter of mango tree is 6-8 m and average trunk height is 1.5 m.
4. The average ring diameter (50 %) of canopy is considered as 4.4 m.
5. The average periphery of the ring basin is considered as 12 m.

Table 3.1 Recommended fertilizer dose of complex fertilizer

Sr. No.	Fertilizers	Quantity required, kg			
		Straight fertilizer			Complex fertilizer
		Urea	SSP	MOP	
1.	Straight	3.255	3.125	0.835	-
2.	N:P:K 15:15:15	2.17	-	-	3.33
3.	16:16:16	2.17	-	-	3.125
4.	17:17:17	2.17	-	-	2.940

(Calculations of fertilizer dose of complex fertilizer are given in Appendix-E).

3.3.2 Equipment Requirement

The machine was designed to fulfillments of fertilizer application in orchards. The following assumptions were made while designing a fertilizer application system for mango orchards.

a. Fertilizer hoppers should hold sufficient quantity of Vermicompost and complex chemical fertilizer.
b. The fertilizer stored in the feed hopper fed to the feed roll either by gravity or by an external force. The delivery of the fertilizer be activated by agitators or screw conveyors or shakers.
c. There should be provision of changing fertilizer rates.
d. Metering of the required fertilizer rate should be reliable and easy to adjust.
e. There should be provision of changing depth of operation.
f. Placing of fertilizer at an appropriate depth and covering with soil layer.
g. Easy removal of the fertilizer left in the box and easy access to clean the inside of machine.

h. Operating efficiency should not be dependent on its inclination when fertilizing undulated fields and should be independent to the operational speed.
i. The cost of operation of machine should be low.
j. All parts should be easily assembled and dismantled for inspection and repair.

3.4 Development of fertilizer application system

Based on agronomic requirement of mango orchards and assumptions made, the power weeder operated fertilizer application system for mango orchards was developed by designing the individual components. The designs of various components are described below.

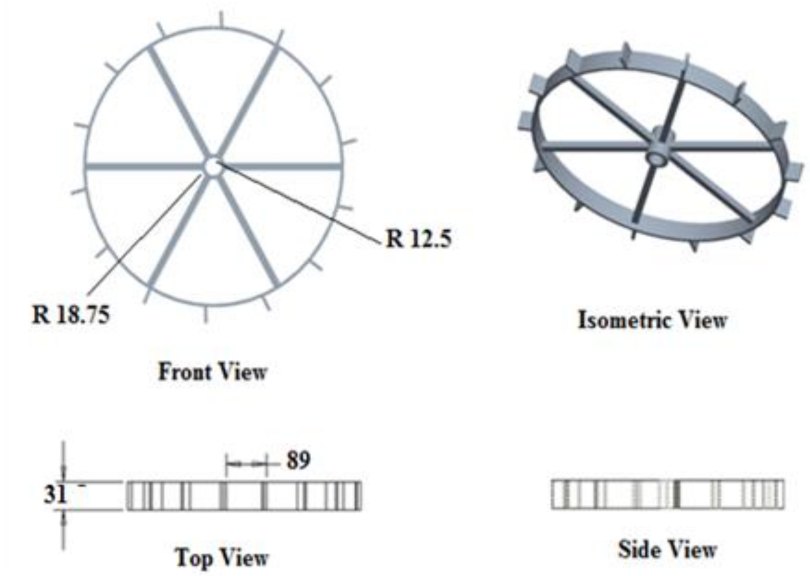
3.4.1 Drive wheel

3.4.1.1 Selection of type of drive wheel

The metering mechanism of a fertilizer application system is driven by the drive wheel. Selection of type of drive wheel to be used on drill depends on the ground conditions. When the drive wheel carries the weight of machine as well as the fertilizer stored in the boxes, the load on the wheel was sufficient to enable the power transmission from the wheel to the metering device. Generally, two types of wheels are used; pneumatic and rigid steel wheels. Rigid wheels are mostly used because of their low cost, low maintenance and long life. The function of wheel is to provide support to equipment and supply power to metering mechanism. It helps in balancing, minimizing the vibrations and controlling the depth of operation. To develop better grip on the soil, small lugs were provided on the periphery of the wheel.

3.4.1.2 Design of drive wheel

In this fertilizer application system, the transport wheels acts as drive wheel and depth control. The details of drive wheel of developed power fertilizer application system for mango orchards are shown in Fig. 3.1. The drive wheel were made up of MS flat 31 mm × 5 mm and 0.40 m effective diameter. The 14 lugs were provided on outer periphery of drive wheel with 25 mm height. The wheel was placed on wheel axle of 37.5 mm diameter. Power was transmitted through the chain and sprocket mechanism to the Vermicompost agitating unit and fertilizer metering unit.



All dimensions are in mm

Fig. 3.1 Drive wheel of developed power weeder operated fertilizer application system

3.4.2 Fertilizer hopper

Fertilizer hopper stores the fertilizer and delivered during the field operations. Fertilizer hopper was designed to cover the full width of the machine. Generally the cross-section of fertilizer hopper is trapezoidal, rectangular, triangular and cylindrical. The bottom of fertilizer box is usually flat. In the developed fertilizer applicator cross section of Vermicompost and fertilizer hopper was trapezoidal for the free flow of Vermicompost and fertilizer without bridging. Vermicompost and fertilizer hopper were separately mounted on the frame. The angle of inclination was 40˚ and 42.5˚ of the Vermicompost and fertilizer hopper with the horizontal considering free flow of Vermicompost and fertilizer respectively. The location of hopper kept 40 to 90 cm above the ground. This height of hopper helps to reduce the angle of inclination of fertilizer delivery tubes which affects the time of travel of fertilizers. In order to reduce the time of travel from the metering unit to the furrow to a minimum and deposit the fertilizer at the low terminal velocity, the fertilizer hopper was placed at 60 cm above the ground level. The design of Vermicompost and fertilizer hopper is as presented below.

3.4.2.1 Vermicompost hopper

The hopper of machine was designed by considering the parameters like angle of repose, bulk density and moisture content of Vermicompost. The shape of the frame was considered trapezoidal in order to make easy movement of materials inside it. Reddy *et al.,* (2013) provided the trapezoidal shape of manure box. The bottom plate of hopper has orifices to deliver the Vermicompost into secondary hopper and into delivery tube. Application rate is also taken into consideration. The volume of box was determined on the basis of quantity of the materials to be filled in the box as a given bulk density (Varshney *et al.,* 2004). Volume of hopper was designed to hold two tree fertilizer requirements (*i.e.* 50 kg) capacity of Vermicompost. The volume of Vermicompost hopper was calculated by using eq^n 3.4.

$$V= \frac{Q}{\rho} \quad \text{... (3.4)}$$

Where,

V= Volume of box, m^3

ρ =Bulk density of the materials, kg/m^3

Q =Box capacity, kg

$$V = \frac{50}{800} = 0.0625\ m^3$$

Consider spillage losses of 10 %. Therefore, total volume of Vermicompost box,

$$V= 1.1×0.0625$$

$$= 0.06875\ m^3$$

The cross-sectional area of the hopper was determined by,

$$F_c = \frac{V}{L} \quad \text{... (3.5)}$$

Where,

F_c= Cross-sectional area of hopper, m^2

V= Volume of hopper, m^3

L= Hopper length, m

$$= \frac{0.06875}{0.8}$$

$$= 0.08594\ m^2$$

Volume of trapezoidal section (V),

$$V = \frac{1}{2}(a+b) \times l \times h \quad \text{… (3.6)}$$

Where,

V = Volume of hopper, m^3

l = Hopper length, m

h = Hopper height, m

a = Base width of hopper, m

b = Top width of hopper, m

The base width of hopper was assumed as 300 mm and the height of hopper was 200 mm .Therefore top width of hopper was calculated by,

$$V = \frac{1}{2}(0.3+b) \times 0.8 \times 0.2$$

$$0.06875 = \frac{1}{2}(0.3+b) \times 0.8 \times 0.2$$

Therefore,

b = 0.56 m

Details of Vermicompost hopper are shown in table 3.2

Table 3.2 Details of Vermicompost hopper of developed fertilizer application system

Sr. No.	Particulars	Values
1.	Length, m	0.8
2.	Height, m	0.2
3.	Base width, m	0.3
4.	Top width, m	0.56
5.	Volume, m^3	0.06875

The bulk density of Vermicompost is considered as 800 kg/m^3. The capacity of box must be calculated as the total volume of Vermicompost hopper multiplied by bulk density of Vermicompost given in eqn. 3.7. (Varshney et *al.,* 2004).

$$Q = V \times \rho \qquad \ldots (3.7)$$

Where,

Q = Box capacity, kg

V = Volume of box, m^3

ρ = Bulk density of materials, kg/m^3

Hopper capacity, Q = 0.06875× 800

= 55 kg

The Vermicompost hopper was made of 12 SWG MS sheet (Fig. 3.3) and was painted. For easy application and achieve desired fertilizer rate, the adjustable orifice type metering mechanism was used. The agitating shaft was put through Vermicompost hopper and power to drive was taken from drive wheel. The secondary hopper was provided just below the Vermicompost hopper to receive the Vermicompost from Vermicompost hopper and transfer the Vermicompost to delivery tube.

3.4.2.2 Fertilizer hopper

The volume (m^3) of the hopper was determined for four trees as,

$$V= \frac{Q}{\rho} \quad \text{... (3.8)}$$

Where,

V = Volume of box, m^3

ρ = Bulk density of the materials, kg/m^3

Q = Hopper capacity, kg

$$V = \frac{22}{1080} = 0.0204 \text{ m}^3$$

Consider spillage losses of 10 %. Therefore, total volume of fertilizer box,

V= 1.1×0.0204

= 0.02244 m^3

The cross-sectional area of the hopper was determined by,

$$F_c = \frac{V}{L} \quad \text{... (3.9)}$$

Where,

F_c= Cross-sectional area of hopper, m^2

V= Volume of hopper, m^3

L= Hopper length, m

$$= \frac{0.02244}{0.8}$$

= 0.02805 m^2

$$\text{Length of hopper (L)} = \frac{V}{A}$$

Therefore,

Area of hopper (A) = V × L

A = 0.01796 m^2

The top width of hopper was assumed as similar to the length of hopper *i.e.*800 mm and the height of hopper was 220 mm and angle of inclination to horizontal was 42.5^0 .Therefore base width of hopper can be calculated by,

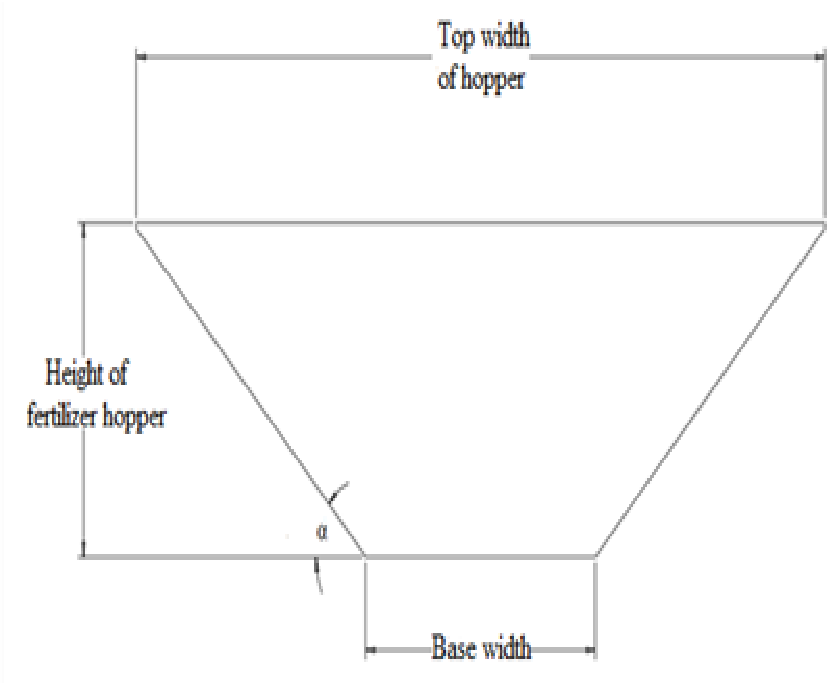


Fig. 3.2 Cross section of fertilizer hopper of developed fertilizer application system

Base width of fertilizer hopper = $\frac{A}{H} - H\cot\alpha$ ... (3.10)

$$= \frac{0.1045}{0.22} - (0.22 \cot 42.5)$$

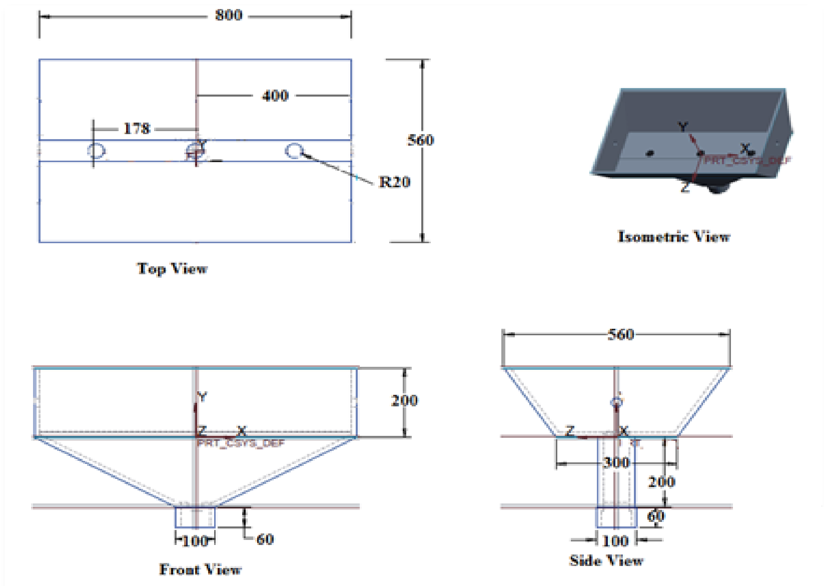
$$= 0.24 \text{ m}$$

Hopper capacity = V_f x ρ … (3.11)

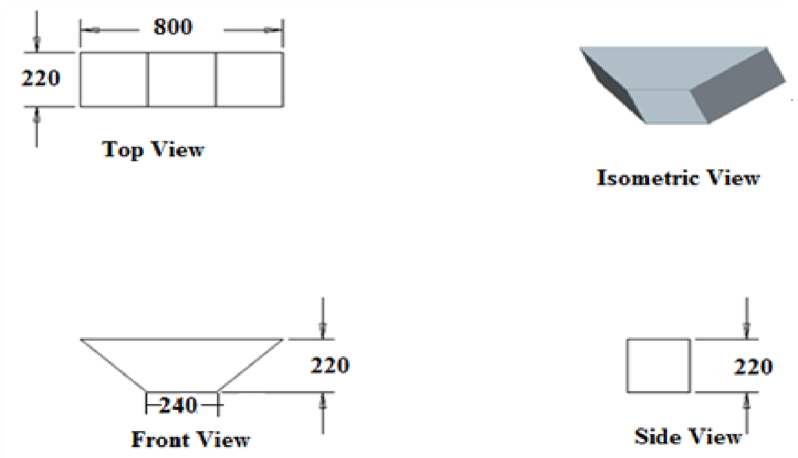
= 0.023 x 1080

= 24.65 ≈ 25 kg

On the developed fertilizer application system, fertilizer hopper was provided with dimensions 800 x 240 x 220 mm. The fertilizer hopper was made trapezoidal in shape with area 0.02805 m^2, volume 0.02244 m^3 and capacity was 25 kg. The fertilizer hopper was made of 12 SWG MS sheet and was painted (Fig 3.3). The provision was made to close the openings of holes on fertilizer hopper during turn and transport. The secondary fertilizer hopper was provided just below the fertilizer hopper and fertilizer metering mechanisms were provided in the secondary fertilizer hopper. One circular pipes of 50 mm diameter with 40 cm length were provided at the bottom of the secondary fertilizer hopper to carry fertilizer upto furrow opener.



(a) Vermicompost hopper



(b)Fertilizer hopper All dimensions are in mm

Fig. 3.3 Details of Vermicompost and fertilizer hopper of developed power weeder operated fertilizer application system for mango orchards.

3.4.2.3 Thickness of Vermicompost and fertilizer hopper

The thickness of Vermicompost and fertilizer hopper was calculated by using following formulas (Sharma and Mukesh, 2010).

$$t_s = \frac{\sqrt[3]{3 \times \rho \times a^2 \times h^2}}{4 \times a \times b_s} \quad \text{.... (3.12)}$$

Where,

t_s = thickness of Vermicompost hopper and fertilizer hopper

ρ = Bulk density, kg/m^3

a = bottom width of Vermicompost and fertilizer hopper, cm

h = height of Vermicompost and fertilizer hopper, cm

b_s = bending stress, kg/cm^2 (let, b_s = 1000 kg/cm^2)

a. Thickness of Vermicompost hopper

Bottom width of hopper = 30 cm,

Height of hopper = 20 cm,

Bulk density of Vermicompost = 0.0008 kg/cm^3

Put these values in eq^n. 3.12

$$t_s = \frac{\sqrt[3]{3\times 0.0008\times 30^2\times 20^2}}{4\times 30\times 1000}$$

= 0.26 cm = 2.6 mm = 3 mm

b. Thickness of fertilizer hopper

Bottom width of hopper = 24 cm,

Height of hopper = 22 cm

Bulk density of fertilizer = 0. 000108 kg/cm^3

Put these values in eq^n. 3.12

$$t_s = \frac{\sqrt[3]{3\times 0.000108\times 24^2\times 22^2}}{4\times 24\times 1000}$$

= 0.29 cm = 2.9 mm = 3 mm

3.4.3 Design of metering mechanism

A metering device draws fertilizer from bulk and delivers them at the desired rate in the fertilizer tube for fertilizing. The device should not cause the mechanical damage to the Vermicompost and fertilizer while in operation. The metering mechanism helps to meter the Vermicompost and fertilizer with its uniform rate.

The various types of metering mechanisms are used for fertilizer drill such as fluted roller, internal double run, orifice type metering mechanism, vertical cup type roller with cell on its periphery, cup feed type metering mechanism. The orifice type metering mechanism and vertical cup type roller with cell on its periphery was chosen for Vermicompost and fertilizer metering respectively. The orifice type metering mechanism and vertical cup type roller with cell on its periphery type metering mechanism meters the fertilizer in group and maintains uniform distribution. The design of metering mechanism is given below.

3.4.3.1 Metering mechanism for Vermicompost

While designing the metering mechanism, prime consideration was given to use simple design not causes any mechanical damage, low cost and easy to fabricate. The adjustable orifices with agitator type mechanism do not damage Vermicompost and meters in desired for placement. Non-uniform pressure distribution and frictional forces among the granules results in arching or bridging. The flow rate is affected by the physical properties of the materials as well as size and shape of the orifices and the container. Factors affecting the flow of solids materials are container geometry, orifice shape and head to orifice diameter ratio. The design methods given by Beverloo *et al*., (1961) for metering of granular through orifices was adopted.

Beverloo *et al*., (1961) developed the equation for flow of solids through orifices as:

$$Q = 35\ \rho\sqrt{g}\ (B-1.4\ d)^{2.5} \qquad \text{.... (3.13)}$$

Where,

Q = flow rate in g/min,

ρ = bulk density in g/cm^3,

g = gravitational acceleration = 981 cm/s^2,

B = orifice diameter in cm and

d = average screen size of particles in cm.

The three different operating speeds are to be followed i.e. 1 km/h, 1.5 km/h, and 2 km/h for operation. The diameter of the opening has been designed on the basis of required application rate and speed of operation. The application rate was as per recommendation of Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, for a tree age of 15 to 20 years giving fruit yield up to 300 fruits, nutrient dose recommended is 50 kg organic manure or 25 kg Vermicompost. The recommended dose of Vermicompost i.e. 25 kg/tree was selected for design. The average periphery of the ring basin is considered as 12 m. Therefore time required to cover 12 m distance with 1, 1.5 and 2 km/h were 42, 28 and 21 seconds respectively. At 2 km/h speed, the time available for flow of required quantity of Vermicompost is least. Hence 2 km/h speed was considered for design of size of opening. The diameter of opening/orifice is calculated by equation. 3.13.

$$Q = 35\ \rho\sqrt{g}\ (B-1.4\ d)^{2.5}$$

$$71428.58 = 35\times0.80\times\sqrt{981}\ (B-1.4\times0.3)^{2.5}$$

$81.45 = (B-0.42)^{2.5}$

$\sqrt[2.5]{81.45} = B - 0.42$

B = 6.23 cm ≈ 6.5 cm for 2 km/h.

The required maximum diameters of opening/orifice are 4.8, 5.6 and 6.5 cm for 1, 1.5 and 2 kmph speed respectively. Bahram *et al*. (2014) revealed that the greater moisture content and smaller particle size caused poor flowability of Vermicompost. Increase in the moisture content and decrease in the particle size, decreases the Vermicompost flowability from free flowing. To avoid a clogging problem of Vermicompost and to get required flow through opening, the area of opening shall be 10 % more than required area of opening.

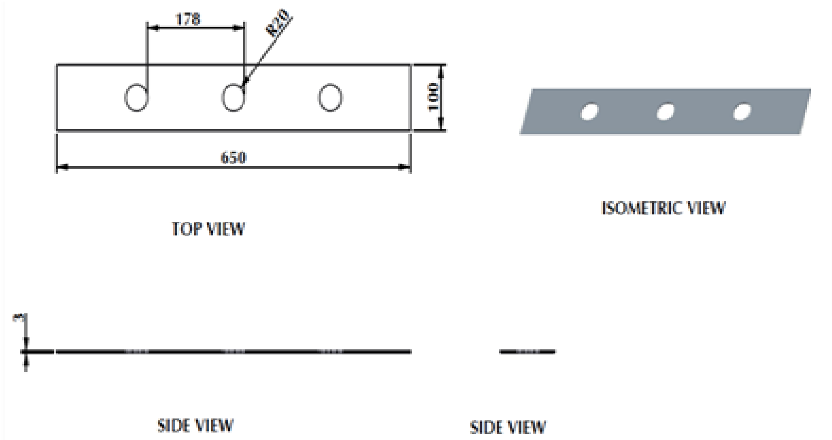
To obtain uniform distribution of Vermicompost along the length of hopper instead of providing single opening, three openings along length of hopper will be desirable. The area of three openings provided at hopper bottom be kept equivalent to area of opening 6.5 cm diameter orifice. The size of each opening found to be 40 mm i.e. area of three 40 mm opening equal to area of 65 mm one opening. The materials meter from these holes were collected in secondary hopper and fed them to the fertilizer tube through fertilizer delivery channel in the ring basin. The size of opening can be changed by slider plate provided at bottom of hopper. The specifications of orifices are given in Table 3.3.

Table 3.3 Specification of orifice for Vermicompost metering mechanism

Sr. No	Opening position of orifice	Size of opening cm^2
1.	Full	37.71
2.	¾	25.44
3.	½	13.76

3.4.3.2 Slider plate

One slider plate was provided in the Vermicompost hopper bottom to control the flow rate of Vermicompost. The purpose of this slider plate is to control the flow of Vermicompost from hopper to the secondary hopper through delivery channel. Three openings were provided in the slider plate for release of materials through hopper. The diameter and spacing between openings was same as that of dimensions of opening in hopper. The slider plate slides in the hopper above the opening provided in the hopper bottom. It covers and uncovers the opening, control and adjusts the flow of Vermicompost through outlets. The long heavy rod was provided for its movement. The marking was made on the rods at 1/2 and 3/4 open position of slider plate. The centre to centre distance between each hole was taken as 178 mm. The plate was satisfactory to control the flow of materials from the openings. It is fabricated by GI sheet of dimensions 650 mm × 100 mm × 3 mm. The details drawing with dimensions of this slider plate is shown in fig. 3.4

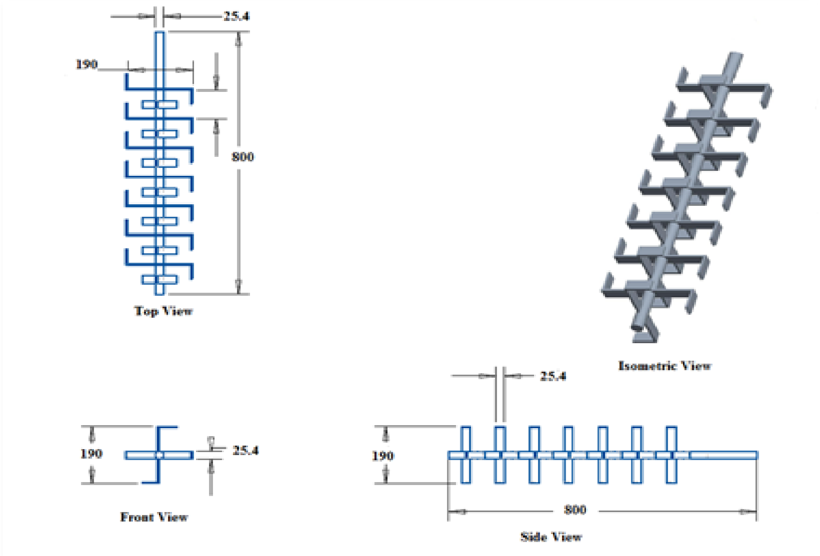


All dimensions are in mm

Fig. 3. 4 Slider plate

3.4.3.3 Agitator

The rotating agitator was designed. It was used as an efficient way to move a wide variety of materials. An agitator is a mechanism which rotates inside the hopper. It mixes and breaks the large particles of Vermicompost inside the hopper for easily expelled out through outlets. The agitator was designed by considering the parameters like, diameter of shaft, length of shaft, number of metal plates, length and width of metal plates, the height of each plate from surface of shaft, spacing between two plates etc. The power was given with the help of chain and sprocket arrangements. The speed of the agitator was same as the speed of the ground wheel. When drive wheel rotates, it transmits power to the agitators. As the agitator rotates, it deeps up into the Vermicompost hopper and mix up the Vermicompost and fed them into the delivery channel. It consisted of shaft on which flat metal plates were welded at a specified distance. The metal plates were welded in helical manner on shaft for giving maximum working efficiency. Each plate was welded on shaft of 2.5 cm diameter at 90° angle. The group of two plate’s forms one complete helix and another group complete helix on opposite direction and it continue up to 07 numbers on both sides. The length of agitator was taken as 800 mm on which 07 numbers flat metal plates were welded on both sides with opposite direction. The dimensions of MS flat metal plate were 80 mm × 50 mm × 5 mm. The distance between two plates was 50 mm. The dimensions and views of agitator are shown in fig. 3.5



All dimensions are in mm

Fig. 3.5 Agitator

3.4.3.4 Fertilizer metering mechanism

Fertilizer is available in solid, liquid or gaseous form. The three major elements in fertilizers are nitrogen, phosphorous and potassium. Most of the fertilizers are available in the granular sizes ranging from 2.5 to 3 mm in diameter. So the fertilizer metering mechanism for granular fertilizer was designed. The required fertilizer rate for mango tree was 5-5.5 kg/tree per year. As working width of power weeder which operate developed fertilizer application system for mango orchards was 0.8 m, with effective drive wheel diameter 0.40 m, 9.55 = 10 revolutions of drive wheel were required to cover 12 m distance for one tree. Considering drive wheel to fertilizer metering mechanism speed ratio as 1:1, the fertilizer rate per revolutions of metering mechanism was given by,

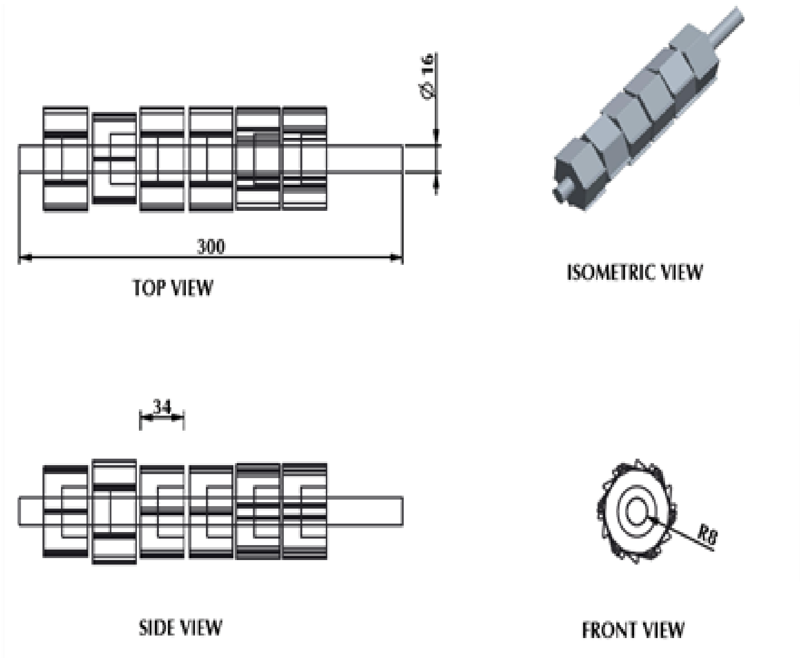
$$= \frac{5500}{10} = 550 \text{ g/revolution} \qquad \text{... (3.14)}$$

Therefore, volume of fertilizer required per revolution of metering mechanism was given by,

$$= \frac{\text{Mass of fertilizer}}{\text{Density of fertilizer}}$$

$$= \frac{550}{1.080} = 509.26 \text{ cm}^3$$

The density of granular fertilizer (urea) is 1072 kg/m^3 and for N:P:K 15:15:15 and 17:17:17 fertilizer is between 1000 – 1200 kg/m^3.The average bulk density for granular fertilizer is considered as 1080 kg/m^3. The 550 g of fertilizer were required per revolutions. To suit requirement of 550 g/revolution of fertilizer, vertical cup type rotor with grooves on its periphery HDPE plastic fertilizer metering rotor with 94 mm outer diameter and 60 mm inner diameter with 34 mm width with 06 grooves available in market was selected. This metering mechanism was fitted in secondary fertilizer hopper. The secondary fertilizer hopper was made from 12 SWG MS sheet and duly coated by paint to avoid corrosion. The fertilizer from main fertilizer hopper flow to secondary hopper by gravity through three openings was provided in the main fertilizer hopper. Provision was made to close these openings during transport. Six fertilizer metering rotor was vertically mounted on shaft. The metering rotors dipped into the secondary fertilizer hopper to scoop the fertilizer. The scooped fertilizer dropped in collection channel which is connected to fertilizer delivery tube. The detail of fertilizer metering mechanism used is shown in Fig. 3.6. The power from drive wheel to fertilizer metering shaft was taken by chain and sprocket as shown in Fig. 3.11.



All dimensions are in mm

Fig. 3.6 Details of fertilizer metering mechanism of developed power weeder operated fertilizer application system for mango orchards

3.4.4 Ridger

Ridgers are used to making furrows, inter-cultivation, earthing operation and shaping ridges. A single bottom ridger is used to making ridges. Ridgers are similar to design and construction to mouldboard ploughs and consists of ridger bottom, adjustable or sliding wings and shank. Ridger bottoms are provided with fixed/sliding type of wings to make furrows according to the requirements. Ridgers are operated in ploughed fields which require a lower draft than unploughed fields to create the desired size of ridges with depth control device.

3.4.4.1 Parts of ridger bottom

The ridger bottom consist of a front share (bar point) or a V-shaped shovel and a rear V or U shaped, fabricated body which performs the function of a shank or Tyne. The share on the ridger is a V-shaped shovel forming an angle of 90° at the tip. For better penetration of the soil, the angle of inclination of the shovel point is kept at 30° to the ground. For good cutting action, the beveled edges are kept sharp. The wings of the ridger are attached to the body by means of hinges and connected with adjustable struts. The normal setting for the wings is 35-50° to the direction of travel. The ridger of developed fertilizer application system is shown in fig. 3.7.

3.4.4.2 Draft of ridger

The draft of the ridger bottom is greatly affected by speed of operation. For design of frame and tynes of the ridger, the draft values of 150 -200 kgf per bottom may be assumed (Anonymous, 1991). Therefore, draft load on ridger tyne/ shank was calculated by,

$$Df = k \times w \times d \qquad \text{.... (3.15)}$$

Where,

Df = draft of ridger, kg or N

k = specific soil resistance, kg/cm^2

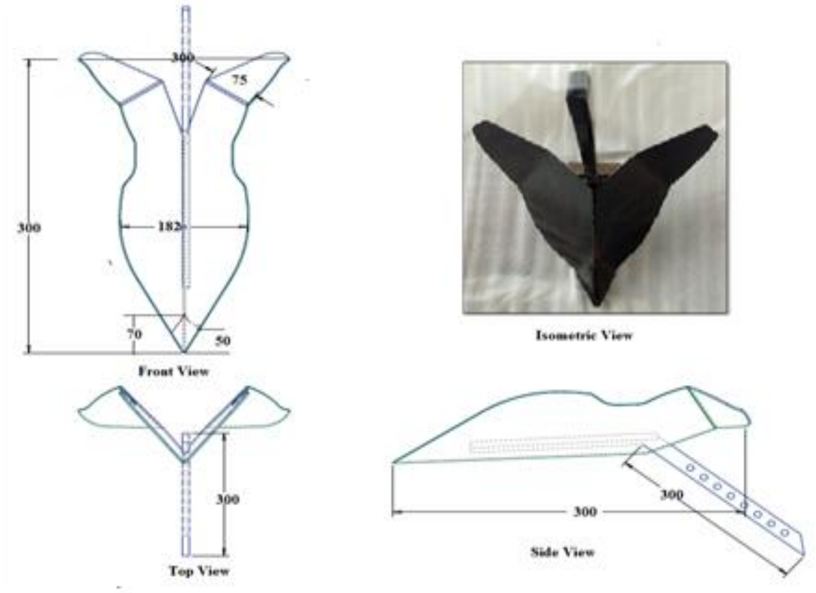
w = width of ridger, cm and

d = depth of operation, cm

$Df = 0.35 \times 30 \times 15$

$Df = 157$ kgf

Therefore, design draft of ridger was 157 kgf.



All dimensions are in mm

Fig. 3.7 Design of ridger of developed power weeder operated fertilizer application system

3.4.5 Design of furrow opener

Fertilizer drills are provided with furrow openers for placement of fertilizer at uniform depths and spacing with minimum dispersion. A shovel type furrow opener was used in developed fertilizer application system. It consisted of shank, share and fertilizer delivery tubes.

3.4.5.1 Design of shank

A shovel type furrow opening tool was attached at one extreme end of shank and the other end of the shank was attached to the frame by nuts and bolts with provision to adjust depth. The depth of fertilizing varies from 10-200 mm. The cross section of the shank was flat. The width and length of the shank were decided on the assumption given below.

Assumptions

1. For medium draft seed drill the draft force is 70 to 90 kg/m width of seed drill and for the silty loam/loam soil, draft force at 2 to 3 km/h speed was 18 kgf/tyne (Jain and Philip, 2003).
2. The draft force acting at a height of h/3 from the bottom of the furrow opener where, the h is total length of furrow opener and tyne.
3. Maximum height of furrow opener shank was taken as 30 cm, but height was adjustable as per the field condition.

Distance of draft application of furrow opener shank (Sharma and Mukesh, 2010) is given as,

$$a = h/3 = 30/3 = 10 \text{ cm} \quad \text{... (3.16)}$$

Moment arm length = (h-a) = (30 – 10) = 20 cm

Bending moment in shank = D (h-a) = 18 × 20 cm ... (3.17)

= 360 kg/cm or 360 ×9.8 ×10 = 35280 N.mm

Factor of safety = 2 (Assumed)

Therefore, maximum bending moment in shank = 35280 × 2 = 70560 N.mm

The section modulus of the shank can be computed from the following equations,

$$Z = M_b / f_b \quad \text{... (3.18)}$$

Where,

M_b = Maximum Bending Moment, N-mm

f_b= Bending Stress, N/ mm^2 (f_b= 56 N/ mm^2 for mild steel)

$\therefore$ Z = 70560/ 56

= 1260 mm^3

We know that,

$$Z = (1/6)\, tb^2$$

$$1260 = (1/6) \times t \times (50)^2$$

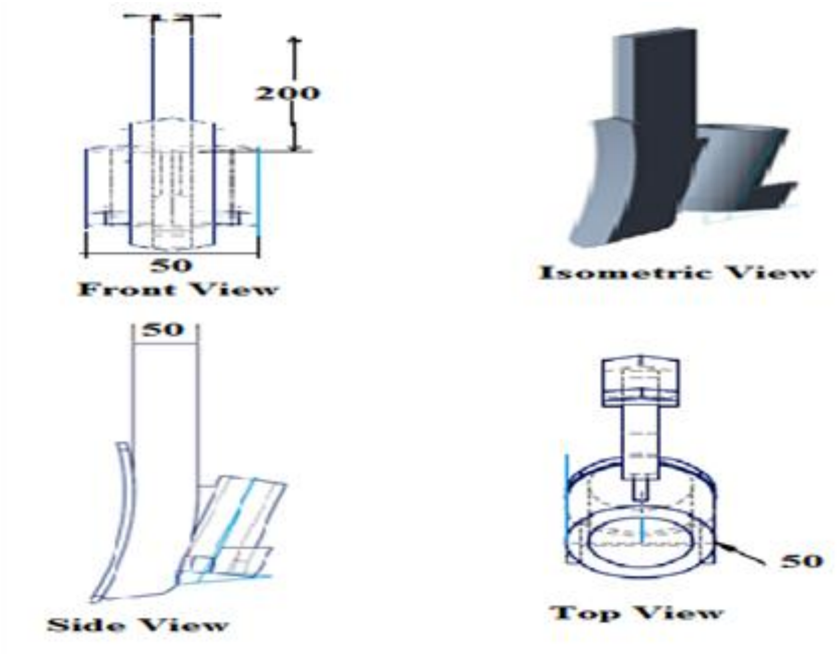
$$t = 3.024 \text{ mm}$$

The MS flat 50 × 12.5 × 320 mm is selected as shank by considering factor of safety 4.

3.4.5.2 Design of shovel

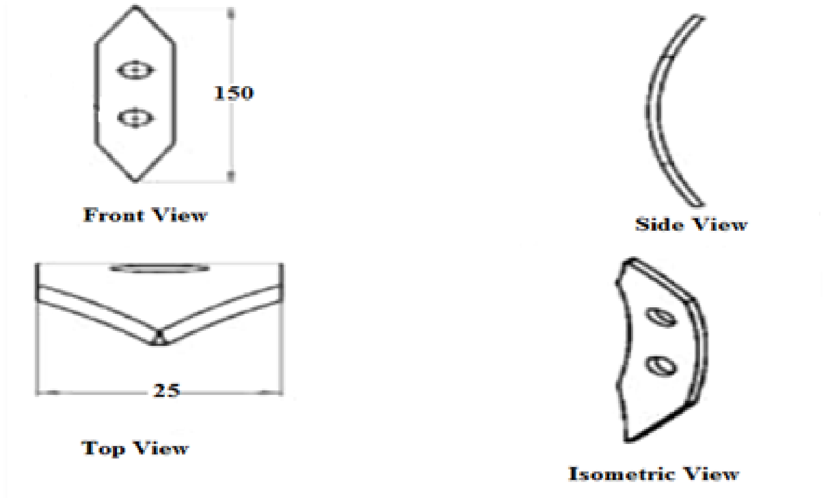
The shovel type furrow opener was fitted to the shank which is attached to the frame. The cross section of furrow opener was 1570 mm^2. The rake angle is 33˚ in order to make cut the soil. The relief angle of the blade was 8˚. The working edge was sharpened and heat treated to reduce wear (Fig. 3.8).

The fertilizer boot was fitted on back of the shovel and shank in inclined position. The 50 mm diameter round pipes boots of fertilizer was 50 cm in length and touches to ground surface to place the fertilizer.



All dimensions are in mm

Fig. 3.8 Design of shovel type furrow opener of developed power weeder operated fertilizer application system



All dimensions are in mm

Fig. 3.9 Shovel of furrow opener

3.4.6 Fertilizer delivery tube

Fertilizer delivery tubes convey the fertilizer from the metering devices to the furrow openers and dropped into the furrow or ridger. Polyethylene tubes of 50 mm diameter and 2 mm thick were used to convey fertilizer from collection channel of secondary hopper to furrow opener by gravity. The inclination of the tubes from the vertical was kept smaller than 20˚ (Anonymous, 1991).

The velocity of a fertilizer falling freely from a height 'h' was given by,

$$V^2 = V_0^2 + 2gh \quad \text{... (3.19)}$$

Where,

V = final velocity of fertilizer due to fall, m/s

V_0 = initial velocity of the fertilizer, (travelling speed) m/s

g = gravitational acceleration, 9.81 m/s^2

h = Height of hopper from drive wheel.

$$V^2 = (0.53)^2 + 2 \times 9.81 \times 0.45$$

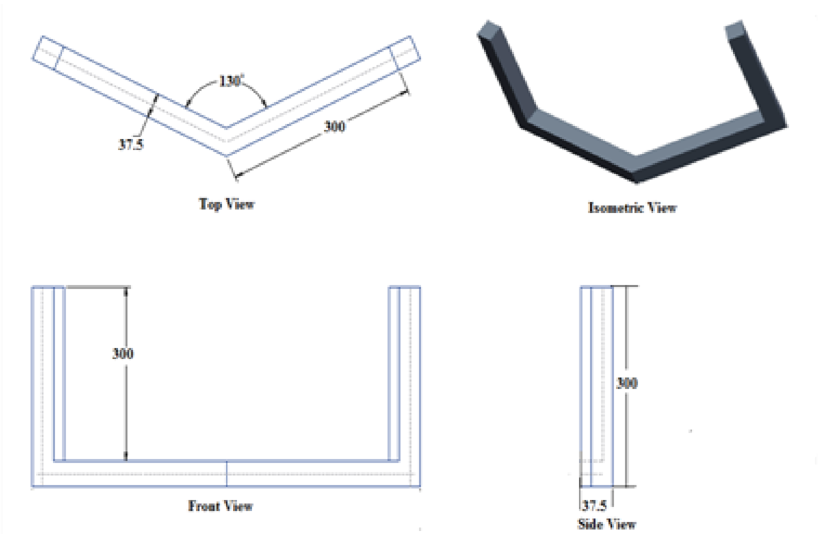
$$= 9.11$$

$$V = 3.02 \text{ m/s}$$

Therefore, velocity of fertilizer falling freely from a height of 45 cm was 3.02 m/s and is acceptable.

3.4.7 Soil covering device

The V-Shaped bund former like soil covering device was provided on the rear side of main frame of the fertilizer applicator to cover the fertilizer in the ring basin**.** The provision was made to control the depth by moving up and down. The soil covering device was designed to covered fertilizer in the ring for efficient use of fertilizer. The details of soil covering device are shown in below Fig 3.10.



All dimensions are in mm

Fig. 3.10 Soil covering device

3.4.8 Power transmission unit

The power required to operate the fertilizer metering mechanism was transmitted from the drive wheel through chain drive. For rotating agitator, chain and sprocket arrangement has been made for power transmission (Reddy *et al.,* 2013). Since the power transmitted to metering mechanism in the fertilizer applicator is very low, the smallest size available chain was used for fertilizer application system. In developed fertilizer application system one intermediate shaft was fitted in between drive wheel shaft and agitating shaft which maintain equal centre to centre distance from drive wheel shaft and agitator shaft. In developed fertilizer application system metering mechanism scoop the fertilizer in bulk quantity and deliver to fertilizer tube through delivery channel. Two idle gears were fitted between intermediate shaft and fertilizer shaft which makes forward drive for agitator and reverse drive for metering mechanism. The schematic diagram is shown in Fig. 3.11. The transmission ratio is maintained 1:1.

The Vermicompost and fertilizer hopper were fitted on the frame of the fertilizer application system in such a way that the center to center distance between sprocket of drive wheel and sprocket of intermediate shaft was 350 mm and from these shaft to agitator shaft was also 350 mm and from shaft to fertilizer shaft was 200 mm. The chain length was calculated by following equations.

$$L = m \times p \qquad \text{... (3.20)}$$

Where,

L = Chain length, mm

m = Number of chain links

p = Chain pitch, mm

Number of chain links was given by equation

$$m = \frac{2C}{p} \times \frac{(Z_1 + Z_2)}{2} + \frac{(Z_2 - Z_1)^2}{2\pi p} \qquad \text{.... (3.21)}$$

Where,

C = center to center distance between two sprockets, mm

Z_1 = number of teeth in driver sprocket

Z_2 = number of teeth in driven sprocket

Let, m_g = number of chain links between drive wheel and intermediate shaft and agitating shaft = 28

m_f = number of chain links between intermediate shaft to fertilizer feed shafts = 16

Therefore, chain length

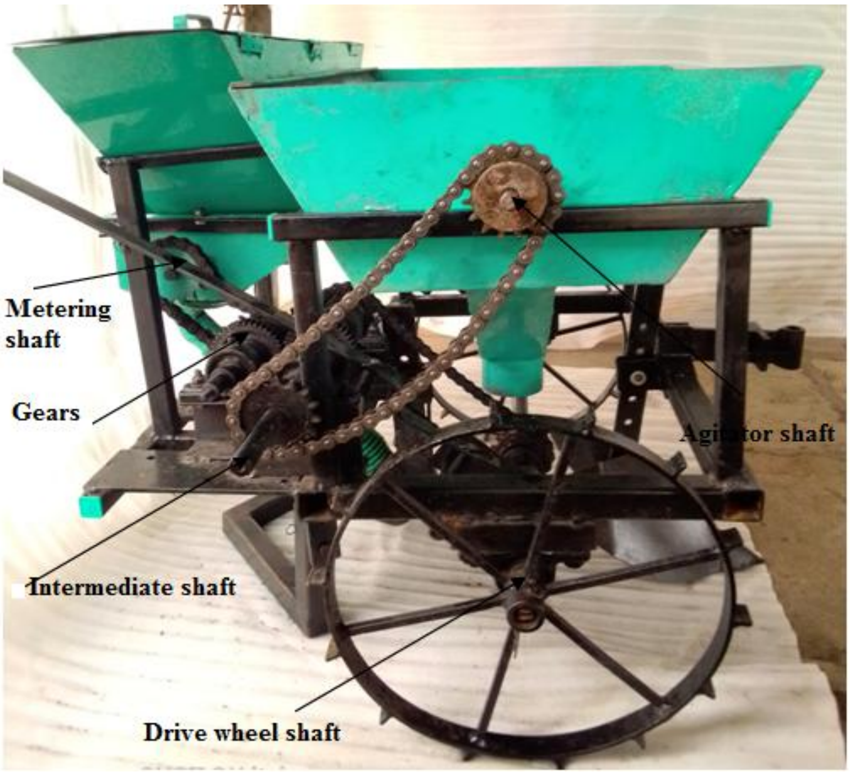
Lg = 1400 mm

L_f = 400 mm was used.

The chain length for drive wheel to intermediate shaft and agitator shaft was 1400 mm and intermediate shaft to fertilizer metering mechanism was 400 mm. The power is transmitted from drive wheel to intermediate shaft and shaft through agitating mechanism and fertilizer metering mechanism.

Table 3.4 Power transmission system in the fertilizer application system

Sr. No.	**Sprocket**		**Number of teeth**
1.	Drive wheel shaft		14
2.	Intermediate shaft	1st sprocket	14
3.	Agitator shaft		14
4.	Metering shaft		14
5.	Drive wheel diameter, cm		40
6.	Metering plate diameter, cm		9.4



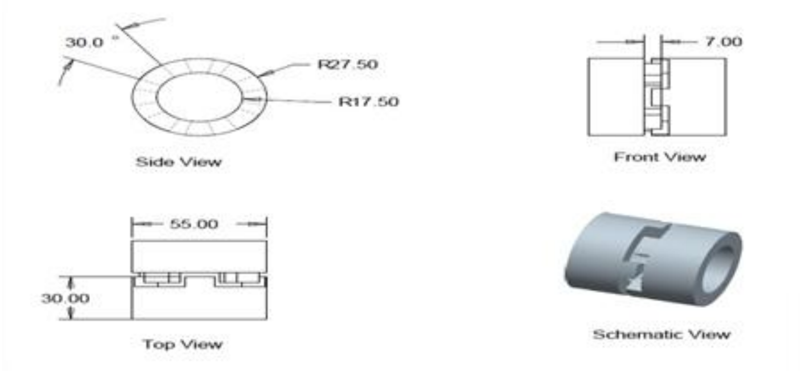
All dimensions are in mm

Fig. 3.11 Power transmission system used for developed fertilizer application system for mango orchards

3.4.9 Clutch

A dog clutch was provided on the drive wheel shaft to cutoff power from drive wheel to metering mechanism while moving from one tree to another tree and during transport. When the clutch was disengaged, the powers do not transmit to the metering shaft. The dog clutch was made by 35 mm MS round bar of length 60 mm.

The three slots were provided on periphery of clutch. The dog clutch plate was welded on drive wheel sprocket and it was in fixed position and another clutch plate was moving forward motion with the help of handle and fork (Fig. 3.12).

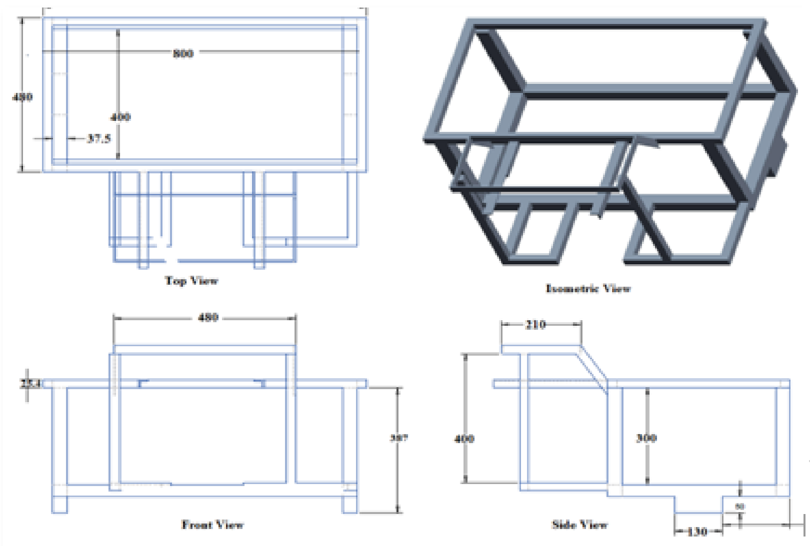


All dimensions are in mm

Fig. 3.12 Dog clutch of developed fertilizer application system for mango orchards

3.4.10 Frame

The main function of the frame is to give rigidity to the all component of machine during uneven vibration in working condition. The frame of fertilizer application system for mango orchards was made of 37.5 × 3 mm MS square pipe of 800 × 480 × 300 mm dimension. All components of developed fertilizer application system assembled and fitted on the frame (Fig. 3. 13).



All dimensions are in mm

Fig. 3.13 Main frame of developed fertilizer application system

3.4.11 Power requirement

Soil resistance has a considerable effect upon the power requirement of weeder. Also, width of cut and speed of operation influences power requirement of weeder. For determining power requirement of the weeder, the soil resistance for silt loam soil was considered to be 0.35 to 0.5 kgf/cm^2 (Basavaraj *et al.*, 2016). Hence the maximum soil resistance for black soil was taken as 0.5 kgf/cm^2. The average operating speed of power weeder in the field was observed as 1-3 km/h. The comfortable working speed in the fields was observed as 1.5 km/h. Considering the difficulties in walking in field of mango orchards and working below the canopy using machine, the maximum speed of operation of the weeder was considered as 2 km/h (0.56 m/s). Total width of coverage of cutting blades was in the range of 80 to 100 cm. The depth of operation was considered as 10 to 20 cm and transmission efficiency as 80 %. Selection of proper prime mover was very important for easy operation and efficient working. Power requirement for power weeder operated fertilizer application system was calculated using following formula (Sahay, 2010).

$$Pd = \frac{Sr \times d \times w \times v}{75} \text{ hp} \qquad \ldots (3.22)$$

Where,

Pd = Power requirement, hp

Sr = Soil resistance, kgf/cm^2

d = Depth of cut, cm

w = Effective width of cut, cm

v = Speed of operation, m/s

Hence, power requirement was calculated as

$$Pd = \frac{0.5 \times 20 \times 30 \times 0.56}{75} \text{ hp} = 2.24 \text{ hp} \qquad \ldots (3.23)$$

3.4.11.1 Total power required

The total power required was calculated as

$$Pt = \frac{Power}{\eta} \qquad \ldots (3.24)$$

Where,

P t = Total power required

η =Transmission efficiency, (0.80)

$$Pt = \frac{2.24}{0.80} = 2.8 \text{ hp}$$

Considering, the overload factor 1.95, the total power = 2.8 × 1.95 = 5.46 hp. Thus, a prime mover as commercially available ASPEE Rotory Tiller (Weeder) with diesel engine (ASPEE (RT/DE 105) of 6 hp for this study was selected.

Fig. 3.14 Power weeder used for developed fertilizer application system

Table 3.5 Specifications of power weeder

Sr. No.	Description	Specifications
1.	Model	RT/DE 105
2.	Engine model	178 Diesel engine
3.	Engine type	4-stroke diesel engine
4.	Horsepower, hp	6
5.	Displacement, cc	296
6.	Fuel tank capacity, lit	3.5
7.	Starting system	Recoil start
8.	Transmission	Gear
9.	Gear shifting	2,1,0,-1
10.	Clutch	Friction plate type
11.	Handle adjustments	Up and down, 360° adjustable
12.	Working depth, mm	150
13.	Working width, mm	600 – 1000

3.4.12 Design of cutting blades

Blades of the rotor are the components which directly interact with soil and as such have major impact on the operation of the weeders. The design of weeder blade involves type and number of blades. The blades were designed and developed based on suitability for tilling operations in mango field. Generally various types of blade geometries are being used as blades for weeders and tillers namely, L-shaped blades, C-shaped blades, J-shaped blades, hatched blades and flat type blades. The C-shaped blades have greater curvature, so they are recommended for penetration in hard field and given better performance in heavy and wet soils. The L-shaped blades are the most commonly used for the fields with crop residue, removing weeds (Bernacki *et al.*, 1972). Hence for present study L shape blade geometry was selected as one of the type.

In rotary weeder, one-fourth of the blades act simultaneously on the soil. The total power of the machine was distributed between the blades. For cutter blade design, number of blade, cutting width and thickness were important parameters. During cutting, blades would be subjected to shearing as well as bending stresses. (Bernacki *et al.*, 1972).

3.4.12.1 Design of rotor with L shape blade

For the rotor with L shape blade following parameter were considered

1) No. of flanges on rotor shaft = 6

2) No. of blades on each rotor = 4

3) Diameter of flange = 100 mm

4) Thickness of the blade =5 mm

5) Width of blade = 50 mm

6) Length of bend portion of blade (Ss) = 50 mm.

7) Length of blade = 200 mm

8) Blade material - M. S.

The bending stress, shear stress and equivalent stress were calculated and these stresses were compared with bending stress, shear stress and equivalent stress of M. S. material. The higher values of the equivalent stresses of the selected material than calculated stress indicated safe design (Bernacki *et al.*, 1972).

The soil force acting on the 4-L shape blades ($K_{e)}$ was calculated by the following equation (Bernacki *et al.*, 1972).

$$K_e = \frac{ks \times cp}{i \times \mathrm{Ze} \times \mathrm{ne}} \qquad \text{.... (3.25)}$$

Where,

Ke = Maximum tangential force, kg,

Cp = Coefficient of tangential force as 2,

i = Number of flanges 6,

Ze = Number of blades on each side of the flanges,

ne = Number of blades which act jointly on the soil by total number of blades.

Hence,

$K_e = \frac{72.55 \times 2}{6 \times 4\ \times 6/24}$

= 24.18 kg

The values of b_e, h_e, S_s and S_1 were considered equal to 2, 25, 70 and 35 mm, respectively, (Bernacki *et al.*, 1972).

Considering the shape of the blades, the bending stress (σ_{zg}), shear stress (τ_{skt}), and equivalent stress (σ_{zt}) were calculated by the following equations (Bernacki *et al.*, 1972).

Bending stress (σ_{zg}) = $6\,\frac{K_e \times S_s}{b_e \times {h_e}^2}$ …. (3.26)

$(\sigma_{zg}) = 6\,\frac{24.18 \times 7}{(0.2 \times 2.52)^2}$

= 812.45 kg/cm^2 = 8.3 kg/mm^2

The shear stress was calculated as,

$(\tau_{skt}) = \frac{3 \times K_e \times S_1}{\left(\frac{h_e}{b_e} - 0.63\right) \times {b_e}^3}$

$(\tau_{skt}) = \frac{3 \times 24.18 \times 0.35}{\left(\frac{2.5}{0.2} - 0.63\right) \times (0.2)^3}$

= 267.37 kg/cm^2 = 2.68 kg/mm^2

The equivalent shear stress was calculated as

$\sigma_{zt} = \sqrt{\sigma_{zg}2} + 4{\tau_{sk}}^2$ …. (3.27)

Where,

σ_{zg} = Bending stress, kg/cm^2,

τ_{skt} = Shear stress, kg/cm^2, and

σ_{zt} = Equivalent stress, kg/cm^2.

Therefore,

$\sigma_{zt} = \sqrt{(812.45)^2\ \ + 4 \times (}267.37)^2$

= 972.64 kg/cm^2 = 9.72 kg/mm^2

Calculated values of stresses were bending stress of 8.3 kg/mm^2, shear stress o 2.68 kg/mm^2 and equivalent stress of 9.72 kg/mm^2. For M.S. the allowable bending, shear and equivalent stresses are 15.80 kg/mm^2, 11.72 kg/mm^2 and 28.28 kg/mm^2, respectively. The obtained value of equivalent stress is less than allowable equivalent stress of M.S. material. Therefore design is safe.

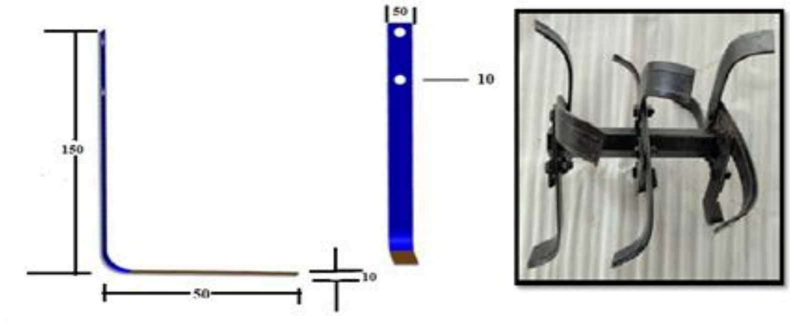


Fig. 3.15 L shape blade

3.4.12.2 Design of rotor with C shape blade

Another blade was developed considering same load, depth of operation and working width. The same rotor shaft was used as L shape blade. The C shape blades were developed to reduce contact area and to resolve the problem of soil mass sticking over the blades. C blades were provided for cutting the soil and for removing the weed. The weeder with C blade gave weeding efficiency up to 87 % (Srinivas *et al.*, 2010). So, the blade angle was taken as 135°similar as Srinivas *et al.*, 2010). The geometry of the blades affects the draft as well as vertical and lateral components of soil forces (Kepner *et al.*, 1978). The 150-200 mm width of cut was the most appropriate within human limitation (Tewari *et al.*, 1993). The width of blade was selected as 200 mm. The total weight of the machine was supported on the blade. By taking total weight of machine as 100 kg, the load acting on one rotor blade shaft is 100/2 i.e. 50 kg.

Considering the unit draft of light to medium soil in Konkan region as 0.35 kg/cm^2, and width of blade 200 mm. The depth of blade was calculated by following equation (Sharma and Mukesh, 2010).

$$\frac{15}{2} \times d \times \text{unit draft} = \text{Load on blade (kg)} \qquad \text{…. (3.28)}$$

Where,

d is the depth of blade.

$$\frac{15}{2} \times d \times 0.35 = 50$$

d = 19 cm = d = 190 mm.

So, the depth of weeding was taken as 190 mm.

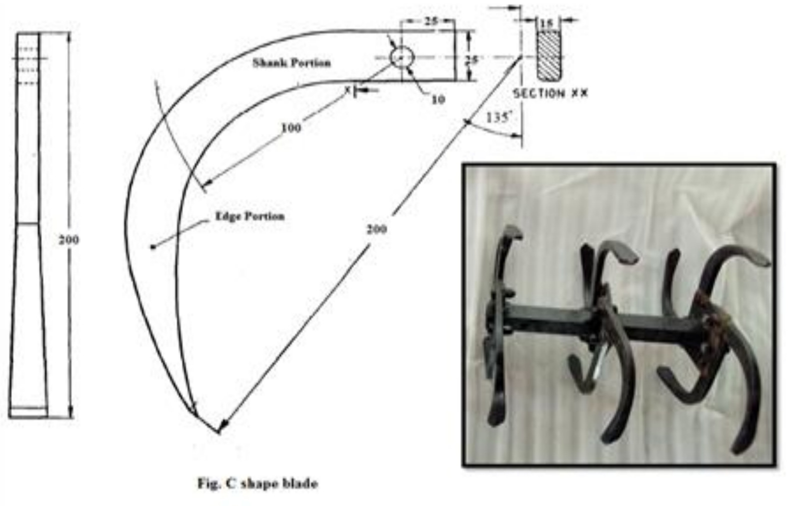


Fig. 3.16 C shape blade

3.4.12.3 Design of rotor with hatched shape blade

Another blade was developed considering same load, depth of operation and working width. The same rotor shaft was used as L shape blade. Different parameters used in the study and have been in consideration to give safe strength and bending values for manufactured blades during weeding operation. For cutter blade design, number of blade, cutting width and thickness were important parameters. During cutting, blades would be subjected to shearing as well as bending stresses. Total working width of the weeder was 300 mm having rotor shaft of length of 800 mm. Total of 24 blades were provided with cutting width of 50 mm. Therefore, four blades were provided on each flange and two flanges were mounted on rotor shaft. The hatched shape blade is shown in fig. 3.17.

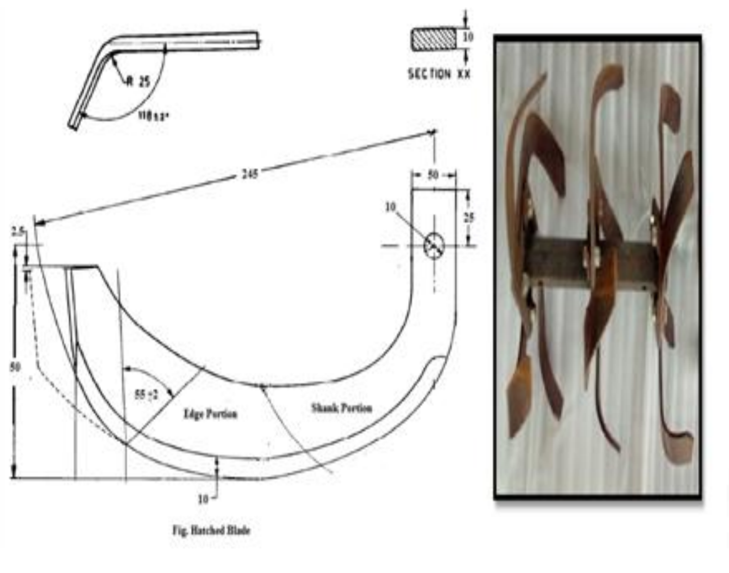


Fig. 3.17 Hatched shape blade

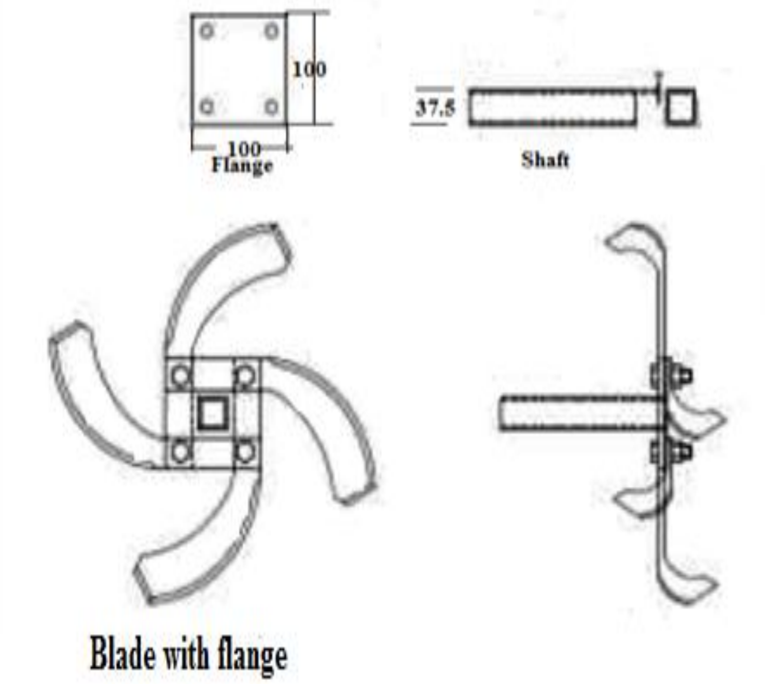


Fig. 3.18 Dimensions of flange with rotor blade

3.4.13 Details of developed fertilizer application system for mango orchards

The fertilizer application system for mango orchards was developed at ASPEE Agricultural Research and Development Foundation, (ARDF) Tansa Farm, Dist. Palghar consists of Vermicompost and chemical fertilizer hopper, orifice type metering mechanism for Vermicompost, agitator, slider plate, fertilizer metering mechanism, drive wheel, power cut-off device, furrow opener, ridger and soil covering device. The shape of Vermicompost and fertilizer hopper was trapezoidal for the free flow of Vermicompost and fertilizer. The angle of inclination of 40˚ and 42.5˚ was made with the horizontal with capacity of 55 kg and 25 kg for Vermicompost and fertilizer respectively. The three openings of 40 mm dia. are provided in Vermicompost hopper and the materials meters from the openings were collected in Vermicompost secondary hopper which was placed just below the main hopper. A plastic vertical cup type rotor with grooves on its periphery type metering mechanism was used for fertilizer metering. Grooves were provided on the periphery of plastic plate of thickness 14 mm. The metering mechanism was actuated by the drive wheel which transmits power by means of chain and sprocket. A clutch was provided to the drive wheel, so that the power can be cut-off from the metering mechanism during moving from one tree to another tree and during transport. Metal tubes of 100 mm diameter and 3 mm thick used to convey Vermicompost from orifice to ridger by gravity and polythene tube of 50 mm diameter and 2 mm thick was used to convey fertilizer from fertilizer secondary hopper to furrow opener.

Ridger and furrow opener are used to place the fertilizer at the desired depth. A ridger is used to dig a ring and place the Vermicompost at a depth of 10- 20 cm. Shovel type furrow opener with the rake angle of 33˚ is used to place the fertilizer in ridge. A provision is made to change the depth by adjusting nut and bolts. Width of ring basin varied between 20-30 cm and depth adjustable to 10-20 cm as per field conditions. At the back side of the frame, a fertilizer hopper, furrow opener and soil covering device are attached. The V-type bund former like soil covering device is attached to the frame. The handle of power weeder is kept free for easy turning and operation below the canopy of tree. An adjustable single point hitching is provided with two adjustable nut and bolts which restricts the lateral movement of fertilizer application system. It gives ease in attachment and adjustment, uniform depth, stability and easy turning of the developed fertilizer application system in mango orchards.

The developed power weeder operated fertilizer application system for mango orchards is shown through Fig. 3.19 to Fig. 3.25. The details of the components, their specifications and the material required are presented in the Table 3.6.

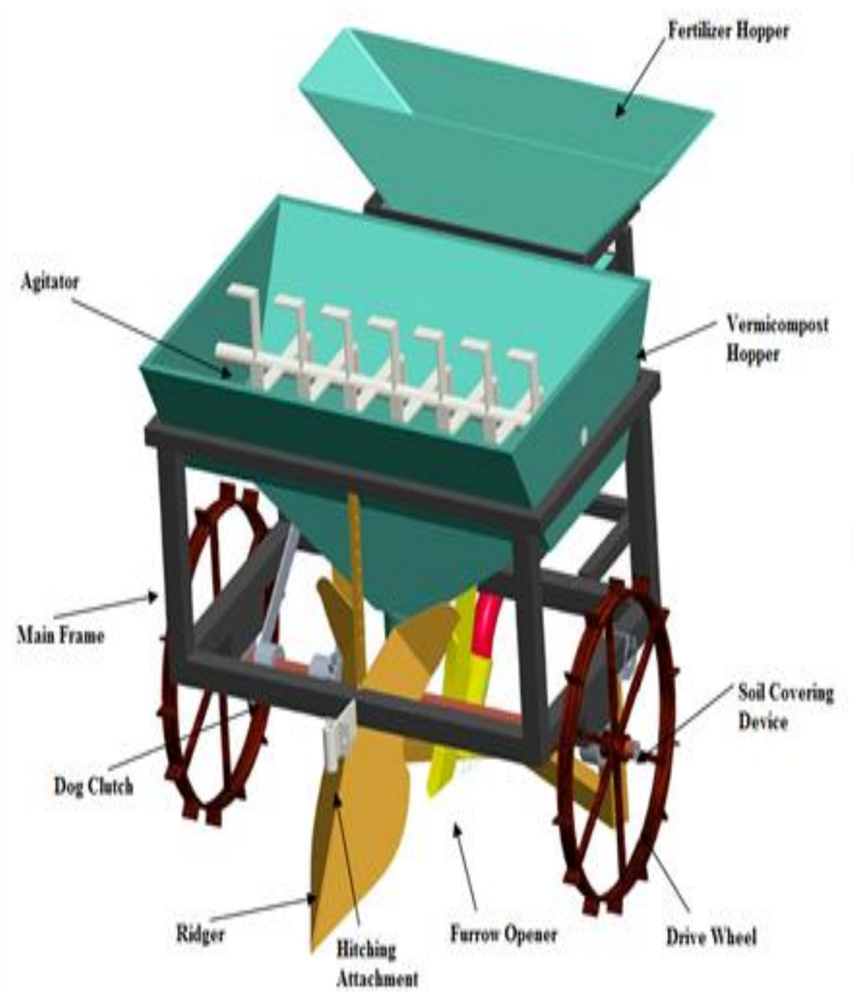
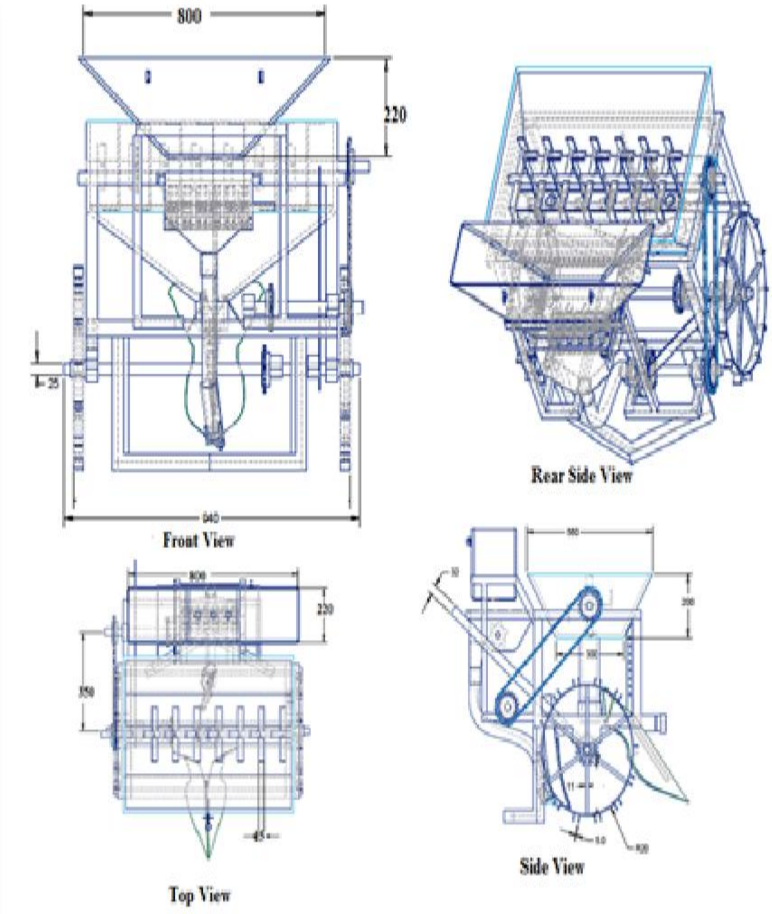


Fig. 3.19 Schematic diagram of developed power weeder operated fertilizer application system for mango orchards



All dimensions are in mm

Fig. 3.20 Details drawing of developed power weeder operated fertilizer application system for mango orchards

Table 3.6 Specification of developed prototype of power weeder operated fertilizer application system for mango orchards

Sr. No.	Components	Specification	Material
1	Drive wheel	Rim diameter: 400 mm, rim width: 31 mm.	MS flat 31×5 mm
2	Vermicompost hopper	Trapezoidal shape with dimensions 800×560 × 200 mm.	12 SWG MS sheet (3 mm)
3	Fertilizer hopper	Trapezoidal shape cross section with dimensions 800× 240×220 mm.	12 SWG MS sheet (3 mm)
4	Vermicompost metering mechanism	Diameter of each orifice 40 mm, distance between two orifices 178 mm.	12 SWG MS sheet (3 mm)
5	Fertilizer metering mechanism	Dia.94 mm and width 34 mm with 6 grooves provided on periphery	Plastic
6	Clutch	Dog clutch, length of handle 1000 mm,	MS flat 25×3 mm
7	Power trans-mission unit	4 Sprocket with 14 teeth, 60 mm dia., chain pitch 12.5 mm, total chain length 1400 mm.	Mild steel
8	Main frame	800 × 480 × 300 mm size frame	MS Square pipe 37.5 ×3 mm
9	Ridger	Height: 300 mm, Shovel width : 50 mm and Thickness: 12.5	Medium carbon steel and 10 SWG MS sheet
10	Shovel type furrow openers	Height of shank 300 mm, C.S. area 1570 mm^2, rake angle 33˚.	Medium carbon steel
11	Fertilizer delivery tube	Diameter 50 mm, thickness 2 mm	Polythene tube
12	Soil covering device	280 × 280 mm length, 160 mm height and 37.5 mm width.	MS square pipe 37.5 ×3 mm

Fig. 3.21 Front view of developed power weeder operated fertilizer application system for mango orchards

Fig. 3.22 Top view of developed power weeder operated fertilizer application system for mango orchards

Fig. 3.23 Rear view of developed power weeder operated fertilizer application system for mango orchards

Fig. 3.24 Side view of developed power weeder operated fertilizer application system for mango orchards

Fig. 3.25 Developed power weeder operated fertilizer application system for mango orchards

3.5 Performance evaluation of developed power weeder operated fertilizer application system for mango orchards

The developed fertilizer application system for mango orchards was tested in the laboratory and in the field as per the standard procedure. It was tested in the mango field situated at ARDF Tansa farm, Dist. Palghar for its performance evaluation. The machine was operated in the laboratory for metering test and for checking uniformity of fertilizing. Developed machine was tested in the field of Alphonso and Kesar varieties of mango. Soil moisture per cent and bulk density were measured by the taking the sample from the 2.5 to 20 cm field depth.

3.5.1 Procedure for operation of fertilizer application system

The developed fertilizer application system consists of Vermicompost and chemical fertilizer hopper, orifice type metering mechanism for Vermicompost, agitator, slider plate, fertilizer metering mechanism, drive wheel, power cut-off device, furrow opener, ridger and soil covering device. The fertilizer applicator was attached to the weeder and operated in a field. The operator assisted in controlling the machine to operate around a mango tree equipped with rotory blades. The handle of the power weeder was kept free for easy turning and operations below the canopy of the tree. The blades of the weeder cultivate the field. The Vermicompost and fertilizer hopper are filled with materials. The Vermicompost hopper consists of an agitator which rotates inside the hopper and mixes and breaks up the large particles of

Vermicompost inside the hopper for easily expelled out through outlets. The feed rate can be adjusted by slider plate opening. The fertilizer hopper metering mechanism also gets power from the drive wheel. The ridger was attached on the front side of the developed fertilizer application system which digs the ridge or ring. The materials dropped from the Vermicompost and fertilizer hopper is placed in the digged ridge. The soil covering device covers the ridge after fertilizer placement. After completion of fertilizer application of one tree power is cut-off from the drive wheel to the metering mechanism and system is taken to next tree for fertilizer application.

3.5.2 Laboratory test

3.5.2.1 Calibration for Vermicompost

The developed machine was tested for Vermicompost application rate. It was done to determine the dropping rates obtainable at a different setting. To test the application rate of Vermicompost at different speeds and different orifice settings, a polyethylene sheet of 12 × 0.60 m was spread on the ground. The fertilizer applicator was run on this polyethylene sheet in such a way that the wheel of power weeder and fertilizer applicator runs on the ground surface and Vermicompost was dropped on the polyethylene sheet. Dropped Vermicompost was collected and weighed to determine the application rate at different forward speeds and different openings of the orifice. Sahu[1] *et al.* (2020) adopted a similar procedure for calibration of FYM applicator.

3.5.2.2 Calibration for fertilizer

It was done to determine the fertilizer dropping rates obtainable at different settings when the machine was stationary. The step by step procedure for calibration was as follows:

i) The fertilizer application system was jack up and a reference point was marked on the drive wheel.
ii) The diameter of drive wheel was measured as 'D' meter.
iii) The nominal width of coverage of the machine determined. The nominal width was calculated by the product of the number of furrow openers 'n' and the spacing between the openers 'd' in m.

$$W = (n \times d)/12 \qquad \text{... (3.29)}$$

iv) The circumference of drive wheel (π × D) was calculated.
v) The fertilizer application system was assumed to be used in a field having length 12 m (Average periphery of tree).

vi) The revolution of the drive wheel required to travel a distance of 12 m was calculated.

$$X = 12/ (\pi \times D) \quad \text{... (3.30)}$$

vii) The ‘X’ revolution was given to the wheel and the fertilizers from the furrow opener were collected. All the collected fertilizer was weighed separately. Let us say the total weight of the fertilizer collected from furrow openers was ‘P’ kg.

Thus, by substituting the value of ‘P’ and ‘X’ revolutions and the quantity of fertilizer to be used in the field was checked. The process was repeated by suitable adjustment till we get desired fertilizer rate (Jadhav 2014).

3.5.3 Field test

The fertilizer applicator was attached to the weeder and operated in a field. The operator gave assistance in controlling the machine to cultivate around a mango tree equipped with blades and fertilizer applicator. The three different operating speeds were found out at different gear and throttle positions. The 1, 1.5 and 2 km/h speed were selected for laboratory and field calibration. The effect of different operating speeds on Vermicompost and fertilizer rate was observed. The fertilizer applicator was operated in a mango field. At each speed, three replications were taken with three different blades and three different chemical fertilizers. The fertilizer application of Vermicompost and three different chemical fertilizers were carried out in the field. The fertilizer applicator was calibrated to find out Vermicompost and fertilizer rate, fuel consumption, depth of ring basin, field capacity, field efficiency and cost of operation for fertilizer application system. The following procedure was adopted for the field test.

3.5.3.1 Description of field

The condition of field affects performance of machine and depth of operation. Therefore field condition is important for fertilizing operation.

The following parameters were determined before the fertilizing operation.

I. Condition of field and soil
   a. Moisture content of Soil
   b. Type of soil
   c. Area and shape of field

II. Condition of orchards
   a. Name and variety

b. Planting methods
c. Plant characteristics
d. Row to row and plant to plant distance
e. Height of girth

3.5.3.2 Field preparations

To evaluate the developed fertilizer application system well-tilled loose soil and soil moisture around field capacity is required in the mango field. If soil is dry, irrigate the periphery of the mango tree and allow field to friable field condition. For field preparation weeder with rotory blade cultivate the field 2-3 times around a mango tree. After preparing the field, a developed fertilizer application system was attached to weeder and operated in the field.

3.5.4 Performance testing of fertilizer application system

Performance evaluation of developed fertilizer application system were carried out for,

1. Field capacity
2. Field efficiency
3. Output capacity
4. Fuel consumption
5. Depth of ring basin
6. Cost of operation

3.5.4.1 Field Capacity

3.5.4.1. (A) Theoretical field capacity -

It is the rate of field coverage of the implement, based on 100 per cent of time at the rated speed and covering 100 per cent of its rated width

3.5.4.1. (B) Effective field capacity

It is the actual area covered by the implement, based on its total time consumed and its width.

3.5.4.2 Field Efficiency

Field efficiency is the ratio of effective field capacity and theoretical field capacity expressed in per cent.

$$\text{Field Efficiency } (\eta) = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100 \quad \text{.... (3.31)}$$

3.5.4.3 Output capacity

The output capacity or application rate of the fertilizer application system was calculated for Vermicompost and fertilizer. To calculate the output capacity for Vermicompost and fertilizer, the fertilizer application system was attached to the power weeder, the known quantity of Vermicompost and fertilizer were filled in Vermicompost and fertilizer hopper. The system was operated around a mango tree for complete periphery. The quantity of Vermicompost and fertilizer remaining in the hopper was counted. From these the quantity of Vermicompost and fertilizer required for one tree was found out which is the output capacity per tree. The output capacity per ha was calculated by multiplied the number of trees per ha.

3.5.4.4 Fuel consumption

The fuel consumption of the developed machine was measured as per the standard prescribed method. The fuel tank was filled to its full capacity before and after the test. The quantity of fuel refilled at the end of the test is measured and fuel consumption per tree found out.

3.5.4.5 Depth of ring basin

The depth of the ring basin was measured with two measuring scales. One scale was placed above the digged ridge and another scale was placed vertically in the ridge. The depth or height of the ridge was measured and noted.

3.5.4.6 Cost of operation

For determination of operating cost of the developed fertilizer application system, fixed cost and operating cost was determined. The cost of machine is determined by adding material cost required for material and labour cost for fabricating the fertilizer application system. The life of machine is considered as 8 yrs and annual use of machine as 250 hours according to IS 9164:1979.

Fixed Cost

1. Cost of machine
2. Depreciation (Rs./Hr) = $(C-S) / (L \times H)$ …. (3.32)
3. Interest (Rs. /Hr)

$= ((C+S) / 2) \times I / H$ …. (3.33)

4. Insurance, taxes and shelter (Rs. /Hr.) = 2 % of initial cost

Total fixed cost = 2 + 3 + 4

Variable Cost

1. Operators cost = Wage of operator / Working Hours

2. Repair and maintenance (Rs /Hr) = 10 % of initial cost

3. Fuel cost = Fuel consumed (lit/h) × Fuel charge (Rs.)

Total Variable cost = 1 + 2 + 3

Operating Cost

= Fixed Cost + Variable Cost

Where,

C = Initial cost or cost of machine, Rs;

H= Annual use of machine, hr;

I = Interest rate, %;

L = Total life of machine, yr;

S = Salvage value, Rs.

The details are given in Appendix- H.

3.5.5 Preparation for test

The following points should be considered during preparation for the test:

1. The machine is kept in good operating conditions.
2. All working parts subjected to friction should be lubricated.
3. The nuts and bolts of various components tightened properly.
4. The fertilizer applicator was attached to the weeder.
5. Then Vermicompost and fertilizer hopper was filled with materials.
6. Suitable gear and throttle position are selected as per the requirement of speed and operating speed was selected for fertilizer application.

Then fertilizer applicator was tested below the canopy of the tree and the effect of operating speed, blades and fertilizer on the depth of ring basin, fuel consumptions, field capacity and output capacity was measured.

3.5.5.1 Experimental design and statistical analysis

Response surface methodology was employed to evaluate performance of developed fertilizer application system using three independent parameters Speed of operation (km/h), Types of blades and Types of fertilizer with three levels for Box-Behnken design (BBD) on four dependent parameter, Field capacity (ha/h), Output capacity (kg/tree), Fuel consumptions (lit/ha) and Depth of ring basin (cm).

The design setup consists of 17 experimental runs, including 5 center point runs as given in Table 3.7. The process conditions were examined as independent variables include: A = Speed of operation (km/h), B = Types of blades and C = Types of fertilizer. The optimum conditions of process variables were derived using desirability function. Design Expert Statistical Software package 11.0.0 trial version (Stat-Ease Inc., Minneapolis, MN, USA) was used for statistical analysis. To know the effect of three independent parameter on four dependent parameters and interrelation to obtain optimized operating parameter for operation.

Table 3.7 Statistical experiment design for evaluation of developed fertilizer application system

Sr. No	Factor	Level 1	Level 2	Level 3
1.	Speed of operation, km/h	1	2	3
2.	Types of blades	C	Hatched	L
3.	Types of fertilizer doses	15:15:15 + Urea	16:16:16 + Urea	17:17:17 + Urea

Table 3.8 Experimental design for evaluation of developed fertilizer application system

Run	A: Speed of operation, km/h	B: Types of blades	C: Types of fertilizer
1.	1.5	Hatched	16:16:16 + Urea
2.	2	C blade	16:16:16 + Urea
3.	2	Hatched	15:15:15 + Urea
4.	1	L blade	16:16:16 + Urea
5.	1	C blade	16:16:16 + Urea
6.	1.5	Hatched	16:16:16 + Urea
7.	1	Hatched	17:17:17 + Urea
8.	2	Hatched	17:17:17 + Urea
9.	1.5	Hatched	16:16:16 + Urea
10.	1.5	Hatched	16:16:16 + Urea
11.	1.5	L blade	15:15:15 + Urea
12.	1.5	L blade	17:17:17 + Urea
13.	1.5	C blade	15:15:15 + Urea
14.	2	L blade	16:16:16 + Urea
15.	1	Hatched	15:15:15 + Urea
16.	1.5	Hatched	16:16:16 + Urea
17.	1.5	C blade	17:17:17 + Urea

Fig. 3.26 Placement of Vermicompost and fertilizer by developed power weeder operated fertilizer application system for mango orchards

Fig. 3.27 Field condition after applying the fertilizer in field

The physical properties of Vermicompost, fertilizer were considered, and power weeder operated fertilizer application system for mango orchards was developed. The developed fertilizer application system for mango orchards was tested in laboratory and field as per standard procedure. The performance in terms of depth of ring basin, field capacity, field efficiency, output capacity, fuel consumption and cost of operation of the developed fertilizer application system for mango orchards was evaluated and presented in the next chapter.

CHAPTER IV
RESULTS AND DISCUSSION

This chapter deals with the results obtained from the performance evaluation of the developed power weeder operated fertilizer application system for mango orchards. The performance of the power weeder operated fertilizer application system was tested in laboratory as well as in the field. After satisfactory operation of the machine in the laboratory, the performance of the machine was tested in the mango field at ASPEE Agricultural Research and Development Foundation, Tansa Farm Dist. Palghar. The results are present below.

4.1 Physical properties of Vermicompost, Fertilizer and Soil

Physical properties of Vermicompost were studied at different moisture content. Physical properties of Vermicompost were measured and presented in Appendix C.

4.1.1 Moisture Content

The moisture content of Vermicompost was measured as per procedure and the formula given in 3.2.1.1. The average moisture content of Vermicompost was 36.38 %, 42.20 % and 47.05 %. The detailed observations are presented in Table C1, C2 and C3 - Appendix C. The moisture content is inversely proportional to the dry matter content.

4.1.2 Bulk Density

The bulk density of Vermicompost was calculated as per the procedure given in 3.2.1.2. The bulk density of Vermicompost was found as 788.93, 799.30, and 802.07 kg/m^3 at moisture content 36.38 %, 42.20 % and 47.05 %, respectively. The bulk density increases with increase in moisture content of Vermicompost. The bulk density is inversely proportional to the dry matter content i.e. bulk density increased with a decrease of dry matter content. It can also conclude that the bulk density has a linear relationship to the moisture content. Glancey and Adams (1996) revealed that wet bulk density was dependent on moisture content for all the solid products. Therefore, moisture content and bulk density was an important parameter to design the capacity of fertilizer hopper. The detailed observations are presented in Table C4, Appendix C.

4.1.3 Angle of Repose

The angle of repose of Vermicompost was measured as per procedure and the formula given in 3.2.1.3. The average angle of repose of Vermicompost found to be 31.50°. For the design of Vermicompost hopper it was taken as 40° for free flow of Vermicompost without bridging. The detailed observations are presented in Table C5, Appendix C.

4.1.4 Physical properties of Fertilizer

Physical properties of fertilizer were studied (Shinde *et al.*, 2006). Physical properties of fertilizer are presented in Table 4.1.

Table 4.1Physical properties of fertilizer

Sr. No.	Fertilizers	Bulk density, kg/m^3	Angle of repose, degree
1.	Urea	1065	36.08
2.	N:P:K 15:15:15	1080	37.87
3.	N:P:K 16:16:16	1115	35.43
4.	N:P:K 17:17:17	1072	39.34

4.2 Soil Parameters

Physical properties of soil of experimental plot were recorded before testing of developed machine in field and are presented in Table 4.2. The type of soil of the selected plot was "Black sticky". Soil moisture content was determined by taking 3 sets of samples with 2 replications for field trials. The details of observations are presented in Table D1 and D2 - Appendix D. It was found that the average bulk density of the soil was 1571.17 kg/m^3 at moisture content 19.91 - 23.99 %. The details are presented in Table 4.2.

Table 4.2 Soil parameters

Sr. No.	Particular	Parameters
1.	Soil type	Black sticky
2.	Moisture content, %	19.91 and 23.99
3.	Bulk Density, kg/m^3	1571.17

4.3 Details of developed fertilizer application system

The fertilizer application system consists of Vermicompost and chemical fertilizer hopper, orifice type metering mechanism for Vermicompost, agitator, slider plate, fertilizer metering mechanism, drive wheel, power cut-off device, furrow opener, ridger and soil covering device. The shape of Vermicompost and fertilizer hopper was trapezoidal for the free flow of Vermicompost and fertilizer. The angle of inclination of 40˚ and 42.5˚ was made with the horizontal with capacity of 55 kg and

25 kg for Vermicompost and fertilizer respectively. The three openings of 40 mm dia. are provided in the bottom of Vermicompost hopper and the materials meters from these openings were collected in Vermicompost secondary hopper which was placed just below the Vermicompost main hopper. A plastic vertical cup type rotor with grooves on its periphery type metering mechanism was used for fertilizer metering. Grooves were provided on the periphery of plastic plate of thickness 14 mm. The fertilizer rate can be varied between 4800 to 5200 g/tree depends upon the canopy of tree. The metering mechanism was actuated by the drive wheel which transmits power by means of chain and sprocket. A clutch was provided to the drive wheel, so that the power can be cut-off from the metering mechanism during moving from one tree to another tree and transporting. Metal tubes of 100 mm diameter and 3 mm thick used to convey Vermicompost from orifice to ridger by gravity and polythene tube of 50 mm diameter and 2 mm thick was used to convey fertilizer from fertilizer secondary hopper to furrow opener.

Ridger and furrow opener are used to place the Vermicompost and fertilizer at the desired depth. A ridger was used to digging a ring and place the Vermicompost at a depth of 10- 20 cm. Shovel type furrow opener with the rake angle of 33˚ is used to place the fertilizer in ridge. A provision is made to change the depth by adjusting nut and bolts. Width of ring basin varied between 20-30 cm and depth adjustable to 10-20 cm as per field conditions. At the back side of the frame, a fertilizer hopper, furrow opener and soil covering device are attached. The V-type bund former like soil covering device was attached to the frame. The handle of power weeder was kept free for easy turning and operation below the canopy of tree. An adjustable single point hitching is provided with two adjustable nut and bolts which restrict the lateral movement of the fertilizer application system. It gives ease in attachment and adjustment, uniform depth, stability and easy turning of the developed fertilizer application system in mango orchard.

The developed power-weeder operated fertilizer application is shown in fig. 4.1 and 4.2. The specifications of developed power weeder operated fertilizer application system for a mango orchard is shown in Table 4.3.

Fig. 4.1 Developed power weeder operated fertilizer application system for mango orchards

Fig. 4.2 Operation of developed fertilizer application system in mango orchards

Table 4.3 Specifications of developed prototype of power weeder operated fertilizer application system for mango orchards

Sr. No.	Components	Specification	Material
1.	Drive wheel	Diameter: 400 mm Ø, rim width: 31 mm.	MS flat 31×5 mm
2.	Vermicompost hopper	Trapezoidal shape with dimensions 800×560 × 200 mm.	12 SWG MS sheet (3 mm)
3.	Fertilizer hopper	Trapezoidal shape cross section with dimensions 800× 240×220 mm.	12 SWG MS sheet (3 mm)
4.	Vermicompost metering mechanism	Each orifice of 40 mm Ø, distance between two orifices 178 mm.	12 SWG MS sheet (3 mm)
5.	Fertilizer metering mechanism	94 mm Ø and width 34 mm with 6 grooves provided on periphery	Plastic
6.	Clutch	Dog clutch, length of handle 1000 mm,	MS flat 25×3 mm
7.	Power trans-mission unit	4 Sprocket with 14 teeth, 60 mm Ø, chain pitch 12.5 mm, total chain length 1400 mm.	Mild steel
8.	Main frame	800 × 480 × 300 mm size frame	MS square pipe 37.5 ×3 mm
9.	Ridger	Height: 300 mm, Shovel width : 50 mm and Thickness: 12.5	Medium carbon steel and 10 SWG MS sheet
10.	Shovel type furrow openers	Height of shank 300 mm, C.S. area 1570 mm^2, rake angle 33˚.	Medium carbon steel
11.	Fertilizer delivery tube	Diameter 50 mm, thickness 2 mm	Polythene tube
12.	Soil covering device	280 × 280 mm length, 160 mm height and 37.5 mm width.	MS square pipe 37.5 ×3 mm

4.3.1 Working of developed fertilizer application system

The fertilizer applicator was attached to the weeder and operated in a field. The operator assisted in controlling the machine to operate around a mango tree equipped with rotory blades. The handle of the power weeder was kept free for easy turning and operations below the canopy of the tree. The blades of the weeder cultivate the field. The Vermicompost and fertilizer hopper are filled with materials. The Vermicompost hopper consists of an agitator which rotates inside the hopper and mixes and breaks up the large particles of Vermicompost inside the hopper for easily expelled out through outlets. The feed rate can be adjusted by slider plate opening. The fertilizer hopper metering mechanism also gets power from the drive wheel. The ridger was attached on the front side of the developed fertilizer application system which digs the ring. The materials dropped from the Vermicompost and fertilizer hopper is placed in the digged ring. The soil covering device covers the ridge after fertilizer placement. After completion of fertilizer application of one tree power is cut-off from the drive wheel to the metering mechanism and system is taken to next tree for fertilizer application.

4.4 Laboratory test

A laboratory test was conducted to evaluate the performance of developed fertilizer application system. The developed machine was tested as per the standard procedure. Testing was done to determine Vermicompost and fertilizer dropping rates at different speeds.

4.4.1 Calibration for developed fertilizer application system for Vermicompost

Vermicompost application rate at three different forward speeds was calculated as per the procedure described in section 3.5.2.1. Desired Vermicompost rate was adjusted by the orifice opening position of applicator *viz.* 1/2, 3/4 and full opening at a forward speed of 1, 1.5 and 2 km/h, respectively. A laboratory test was taken of Vermicompost at moisture content of 36.38, 42.20 and 47.05 % for application rate. Calibration details are given in Appendix -F.

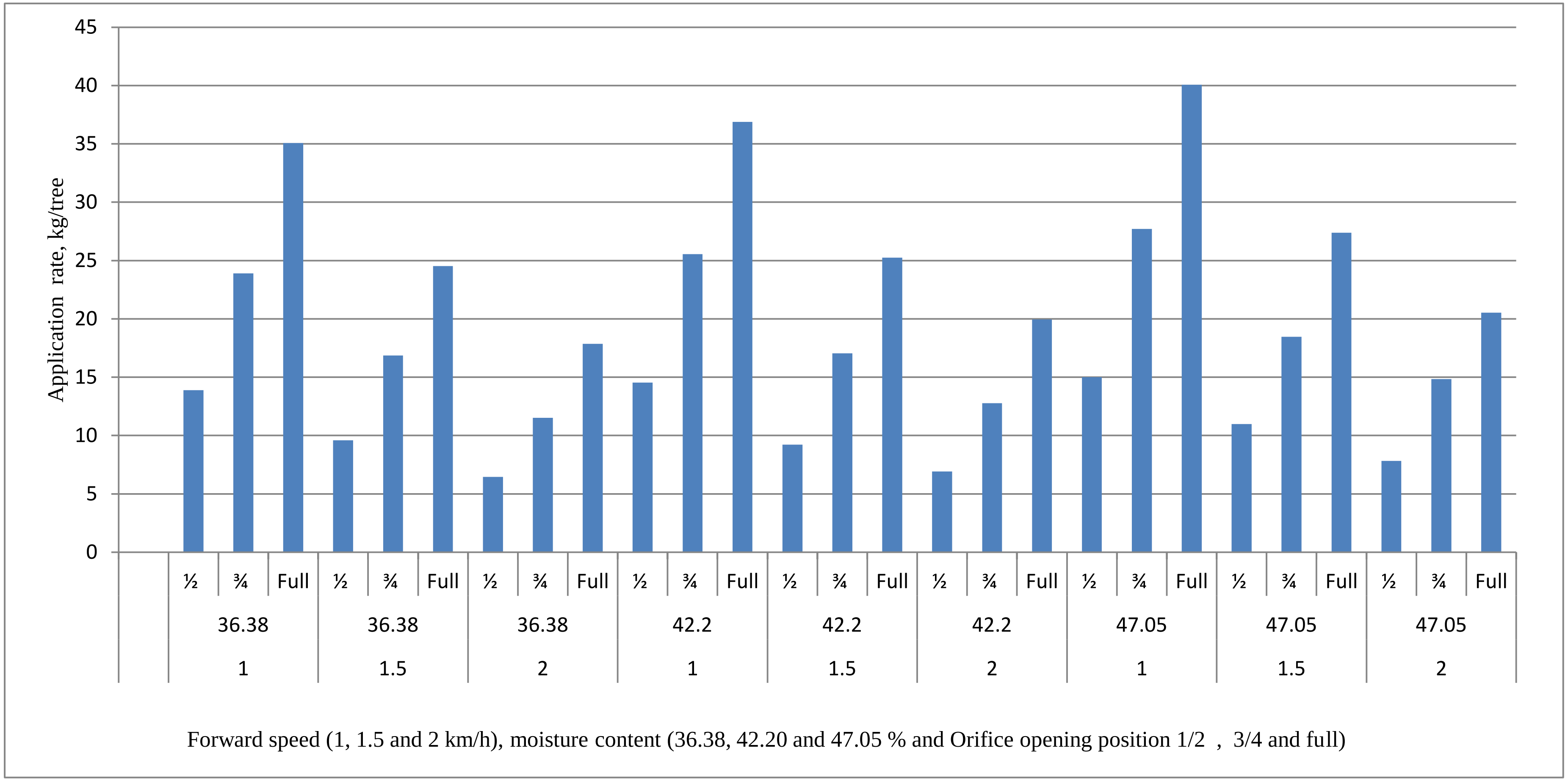


Fig. 4.3 Calibration of developed fertilizer application system for Vermicompost

Vermicompost application rate noted at 1/2 to full orifice opening at moisture content 36.38 to 47.05 %. The obtained result revealed that Vermicompost moisture content increased from 36.38 to 47.05 % increases the Vermicompost application rate. Fig. 4.1 revealed that the Vermicompost application rate increased 13.882 to 35.073 kg/tree with increasing in orifice opening position from 1/2 to full opening at the moisture content of 36.38 %. This was corroborating with the observations of earlier studies of Jain and Lawrence, 2015 and Reddy *et al.,* 2013. A similar trend was observed at all three moisture content and three orifice opening is given in Table F1, Appendix –F.

The Vermicompost application rate increases at the low forward speed of operation. The finding of different orifice openings revealed that the significantly highest application rate (kg/tree) was observed at full orifice opening at a speed 1 km/h. An increase in application rate with an increase in the opening area of the orifice may be due to the availability of more area, allowing an increased quantity of Vermicompost to pass through the orifice. The highest application rate was obtained at a moisture content of 47.05 %. This might be due to the higher amount of moisture in Vermicompost. The orifice opening level and moisture content levels increases, the Vermicompost application rate increases. The care should be taken while use of application system Vermicompost should be free from stone particles, plastic, wood and cloth. A similar observation has also been reported by Singh and Singh (2014). Variation in the application rate of Vermicompost depends on the machine forward speed. If forward speed of the machine decreases and opening area of the orifice increases, increases the Vermicompost application rate.

4.4.2 Calibration of developed fertilizer application system for fertilizer

The test was carried out as per the method given in Section 3.5.2.2. The laboratory testing was done for calibration of fertilizer with vertical rotor type metering mechanism with grooves on its periphery. The length of a strip to cover the canopy of one tree was 12 m assumed. The number of revolutions of the drive wheel required to cover 12 m length were 10. Complex chemical fertilizers 15:15:15, 16:16:16, and 17:17:17 mix with Urea (to get recommended dose of N: P: K) were used for calibration of fertilizer application system. The calibration of fertilizer application system in the laboratory was considered 5 % more fertilizer rate setting than observed in the field based on trials. Three replications were taken for calibrating the fertilizer application system in the laboratory. The average fertilizer rate for complex fertilizer 15:15:15 + Urea from the calibration at 1, 1.5, and 2 km/h was observed as 4926, 4886 and 4836 g/tree, respectively. The observations are presented in Table 4.4. A lower variation was observed in the fertilizer rate. This observed variation may be due to time available for metering mechanism to scoop fertilizer is least at 2 km/h speed.

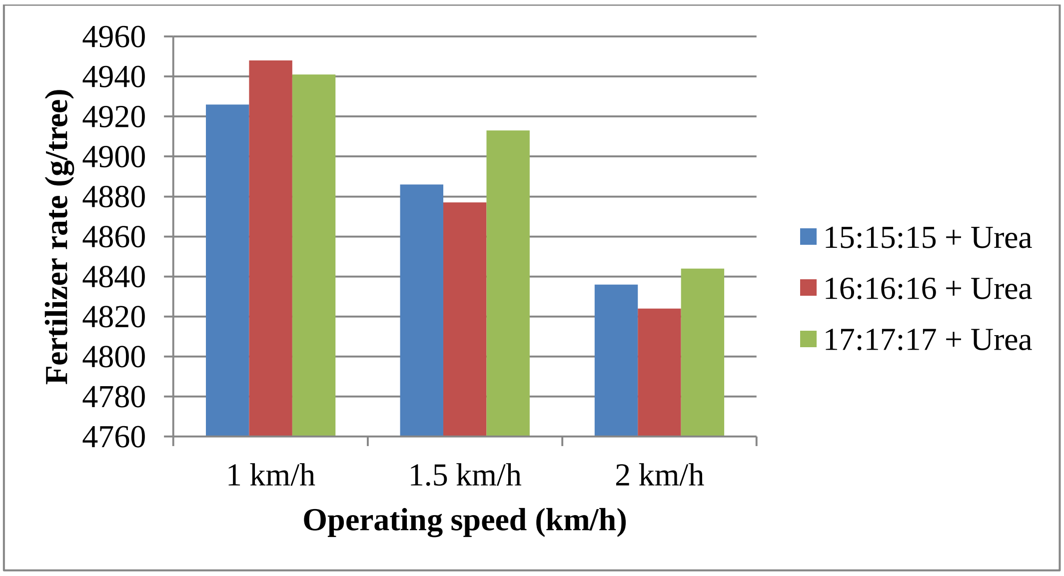


Fig. 4.4 Calibration of developed fertilizer application system for fertilizer

Table 4.4 Fertilizer rate obtained from developed fertilizer application system for mango orchard in laboratory

Type of Fertilizer	Speed, km/h	Fertilizer rate, g/tree			Average, g/tree
		R_1	**R_2**	**R_3**	
15:15:15 + Urea	1	4951	4885	4942	**4926**
	1.5	4909	4887	4862	**4886**
	2	4876	4843	4791	**4836**
16:16:16 + Urea	1	4892	5024	4930	**4948**
	1.5	4890	4877	4865	**4877**
	2	4872	4795	4803	**4824**
17:17:17 + Urea	1	4940	4987	4897	**4941**
	1.5	4894	4932	4915	**4913**
	2	4835	4856	4961	**4844**

The fertilizer discharge rates for each fertilizer were determined separately. Fertilizer discharge rate indicates the capability of metering units to deliver desired fertilizer application rate. The average fertilizer discharge rate for 15:15:15 + Urea fertilizer was found 4926, 4886 and 4836 g/tree, for 16:16:16 + Urea was found 4948, 4877 and 4824 g/tree and for 17:17:17 + Urea fertilizer was found 4941, 4913 and 4844 g/tree at 1, 1.5 and 2 km/h forward speed, respectively.

4.4.2.1 Effect of hopper filling on fertilizer application rate

Effect of fertilizer hopper filling on application rate was tested. The fertilizer application system was calibrated at four hopper settings such as 1/4, 1/2, 3/4 and full filling of hopper. The application rate was observed slightly higher in full hopper. A small difference in application rate indicates little compaction effect with hopper filling in fertilizer hopper. A lower variation was observed in the fertilizer application rate may be due to compaction effect of hopper filling. The observations are presented in Table F2, Appendix F.

4.5 Field testing of power weeder operated fertilizer application system for Vermicompost and fertilizer in mango orchards

The field testing of developed power weeder operated fertilizer application system for mango orchard was carried out at Mango field ARDF Tansa farm, Dist. Palghar.

4.5.1 Description of field

For the operation of the fertilizer application system, well tilled soil is required which had 10-20 cm depth. The plots were tilled before fertilizing by power weeder with different blades below the canopy of the mango tree. The field was given 2-3 times pass with weeder under mango canopy. The details of the field used for the field test are as follows.

Table 4.5 Field conditions during use of developed fertilizer application system

Sr. No.	Particulars		Value
1.	**Condition of field and soil**		
1.1	Size		45m x 45m
1.2	Status		
	1.2.1	Type of soil	Black sticky
	1.2.2	Moisture content of soil, %	19.91 - 23.99
	1.2.3	Bulk density of soil, g/cm^3	1571.17
1.3	Location		ASPEE Agricultural Research and Development Foundation, Tansa farm, Dist. Palghar
1.4	Shape of field		Square
1.5	Length of plot		45 m
1.6	Width of plot		45 m
1.7	Area		2025 m^2 (0.2025 ha)
2.	**Condition of orchards**		
2.1	Name and variety		Alphonso and Kesar

Sr. No.	Particulars	Value
2.2	Planting methods	Square
2.3	Plant characteristics	
	2.3.1 Canopy diameter, m	8.00
	2.3.2 Tree height, m	4.9 ~ 5
2.4	Row to row distance, m	10 × 10
2.5	Plant to plant distance, m	10 × 10
2.6	Height of girth, m	1.2

To evaluate the developed fertilizer application system well-tilled loose soil and soil moisture around field capacity is required in the mango field. If soil is dry, irrigate the periphery of the mango tree and allow field to friable field condition. The weeder with rotory blade operated in 2-3 times around a mango tree. After preparing the field, a developed fertilizer application system was attached to weeder and operated in the field. The operational pattern of fertilizer application was a continuous turn below the mango canopy for digging the circular ring and applying fertilizer in the basin. To know the performance, the developed fertilizer application system was tested at three different speeds, three different blades and three different types of fertilizer.

4.5.2 Field test

The field trial of the developed fertilizer application system was conducted. The developed fertilizer application system was tested at 3/4 and full opening position of the orifice for Vermicompost with three different speeds, three different blades and three different chemical fertilizers as per method given 3.5.3. Developed fertilizer application system was operated at 1, 1.5 and 2 km/h operational speed. The observed plant characteristics during field test are given in Appendix-G.

4.5.2.1 Theoretical field capacity

The theoretical field capacity was calculated as per the procedure given in section 3.5.4.1(A). The mean theoretical field capacity of fertilizer application system was 0.80, 0.97 and 1.29 ha/h at 1, 1.5 and 2 km/h operational speeds respectively. The theoretical field capacity of the developed fertilizer application system was more due to there were no interruptions, no clogging and no refilling of hoppers hence the fertilizer application system works 100 per cent of the time at rated speeds.

4.5.2.2 Effective field capacity

The effective field capacity was calculated as per the procedure given in section 3.5.4.1(B). The average effective field capacity of fertilizer application system was 0.42, 0.47 and 0.58 ha/h at 1, 1.5 and 2 km/h operational speeds, respectively. Due to the higher application rate, the hopper refilling per hectare was more and the time required for hopper refilling and adjustments was more. Hence, effective field capacity was low.

4.5.2.3 Field efficiency

The field efficiency was calculated with the help of equation 3.33 given in section 3.5.4.2. The average field efficiency of fertilizer application system was, 52.5, 48.45 and 44.96 % at 1, 1.5 and 2 km/h operational speeds, respectively. Due to the less effective field capacity and more theoretical field capacity, the field efficiency was low at higher speed.

4.5.2.4 Output capacity of Vermicompost and fertilizer

The output capacity of the developed fertilizer application system was calculated as per the procedure described in section 3.5.4.3. The output capacity for Vermicompost was given in Table 4.6 and 4.7 at 42.20 and 47.05 % moisture content, respectively. The output capacity for fertilizer 15:15:15 + Urea, 16:16:16 +Urea and 17:17:17 + Urea was 5.21, 5.23 and 5.31 kg/tree. The output capacity for Vermicompost and fertilizer varies with periphery of tree as well as lower variation with speed of operation.

Table 4.6 Output capacity of developed fertilizer application system for Vermicompost at 42.20 % moisture content

Run	**Periphery of tree, m**	**Speed of Operation, km/h**	**Output Capacity, kg/tree**
1	12.94	1.50	27.18
2	8.32	2.00	13.15
3	10.40	2.00	17.54
4	10.21	1.00	21.86
5	14.67	1.00	31.91
6	12.57	1.50	26.20
7	10.52	1.00	22.45
8	8.17	2.00	14.03
9	14.45	1.50	29.53
10	14.70	1.50	30.41
11	14.61	1.50	29.12
12	12.88	1.50	27.03
13	12.09	1.50	25.28
14	8.48	2.00	14.12
15	11.37	1.00	24.82
16	17.28	1.50	34.79
17	15.79	1.50	32.28
Average	12.320	-	24.80

Table 4.7 Output capacity of developed fertilizer application system for Vermicompost at 47.05 % moisture content

Run	Periphery of tree, m	Speed of Operation, km/h	Output Capacity, kg/tree
1	15.24	1.50	32.65
2	16.49	2.00	27.09
3	12.80	2.00	21.67
4	11.23	1.00	25.64
5	13.98	1.00	27.47
6	14.77	1.50	30.70
7	14.69	1.00	41.24
8	11.50	2.00	19.96
9	17.28	1.50	34.12
10	16.42	1.50	33.56
11	15.50	1.50	30.50
12	13.67	1.50	28.89
13	16.10	1.50	32.41
14	12.09	2.00	20.86
15	15.71	1.00	33.89
16	11.72	1.50	25.28
17	13.04	1.50	27.09
Average	14.25		29.01

4.5.2.5 Fuel consumption

The fuel consumption of the developed fertilizer application system was measured as per the method given in section 3.5.4.4. The average fuel consumption for one hectare was 3 - 5 l/ha depends upon the canopy of the tree as higher periphery of canopy; more time was required for coverage. The range was higher as variation in its periphery of canopy was higher.

4.5.2.6 Depth of ring Basin

The depth of the ring basin was measured as per the procedure given in section 3.5.4.5. Average depth of ring basin observed were 16.2 and 15.8 cm at 19.91 and 23.99 % soil moisture content, respectively.

4.5.2.7 Operational time

The operational time required to cover one tree was 25 seconds to 1 minute as per the speed of operation and canopy of the mango tree.

4.5.3 Field performance

The performance evaluation of the developed fertilizer application system was carried out by experimental design as discussed in section 3.5.5.1. To minimize number of experiments, to find out interactions of independent and dependent parameters " Design Expert 11" software was used and accordingly combination of parameters for 17 experiments to be conducted were finalized as given in Table 3.8. Accordingly, 17 runs for three independent and four dependent parameters were carried out. The field performance of developed fertilizer application system was carried out at 19.91 and 23.99 % soil moisture content. The experimental runs and observed responses by using RSM are given in Table 4.8.

Table 4.8- Experimental design used to evaluate the effect of operational parameters on performance by RSM at 19.91 % soil moisture content

Run	Periphery, m	Speed of operation, km/h	Types of blades	Types of fertilizer	Field capacity, ha/h	Output capacity, kg/tree	Fuel consumption, l/ha	Depth of ring basin, cm
1	12.94	1.50	Hatched	16:16:16 + Urea	0.50	5.1	4	18.3
2	8.32	2.00	C blade	16:16:16 + Urea	0.65	5.5	3	14.2
3	10.40	2.00	Hatched	15:15:15 + Urea	0.61	5.6	4	17.5
4	10.21	1.00	L blade	16:16:16 + Urea	0.45	4.9	3.5	16.2
5	14.67	1.00	C blade	16:16:16 + Urea	0.39	4.8	3.5	13.6
6	12.57	1.50	Hatched	16:16:16 + Urea	0.50	5.2	4	19
7	10.52	1.00	Hatched	17:17:17 + Urea	0.45	4.8	4	17.3
8	8.17	2.00	Hatched	17:17:17 + Urea	0.65	5.7	3	19.5
9	14.45	1.50	Hatched	16:16:16 + Urea	0.47	5.3	4	17.9
10	14.70	1.50	Hatched	16:16:16 + Urea	0.47	5.5	4	16.4
11	14.61	1.50	L blade	15:15:15 + Urea	0.47	5.1	4	14.3
12	12.88	1.50	L blade	17:17:17 + Urea	0.50	5.3	4	16
13	12.09	1.50	C blade	15:15:15 + Urea	0.50	5.5	4	14.8
14	8.48	2.00	L blade	16:16:16 + Urea	0.65	5.7	3	15.5
15	11.37	1.00	Hatched	15:15:15 + Urea	0.45	4.5	3.5	16.5
16	17.28	1.50	Hatched	16:16:16 + Urea	0.45	5.5	4	17
17	15.79	1.50	C blade	17:17:17 +Urea	0.45	5.4	4	15.2

4.5.3.1 Field performance of developed fertilizer application system at 19.91 % soil moisture content

The effect of operational parameters on the performance of fertilizer application system was studied and discussed in the following subsequent headings. Response surface methodology was used for the analysis of observed responses after eliminating some non-significant terms (P≥0.10) and predicted models tested for adequacy and fitness using analysis of variance.

4.5.3.1.1 Field capacity

As mentioned in section in 3.5.4.1(B), the field capacity of fertilizer application system was determined. The Fig. 4.5 indicates that, the field capacity increased with increase in speed of operation. It was observed that the maximum field capacity of 0.65 ha/h was found at speed 2 km/h with all three blades. It might be due to less time required for operations as compared to other speeds. Fig. 4.6 indicates the effect of speed of operation and types of fertilizer. The field capacity increased with increase in speed of operation. Maximum field capacity observed 0.65 ha/h at 2 km/h speed with all three fertilizer. The Fig. 4.7 shows the effect of types of blade and types of fertilizer on the field capacity. The types of blade and types of fertilizer do not have effect on field capacity as field capacity depends on speed of operations.

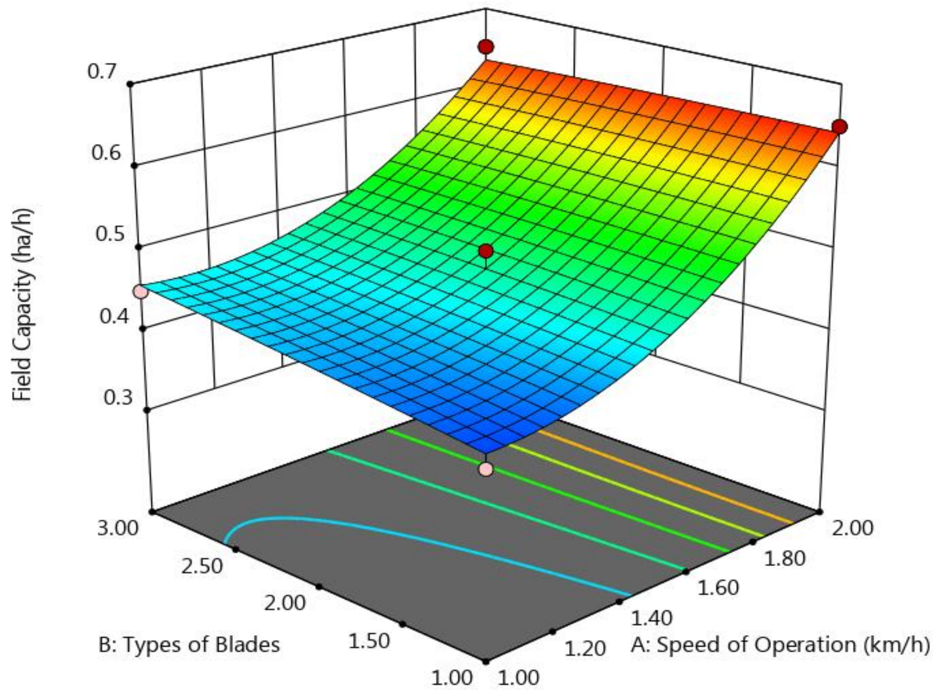


Fig. 4.5 Effect of speed of operation and types of blade on the field capacity

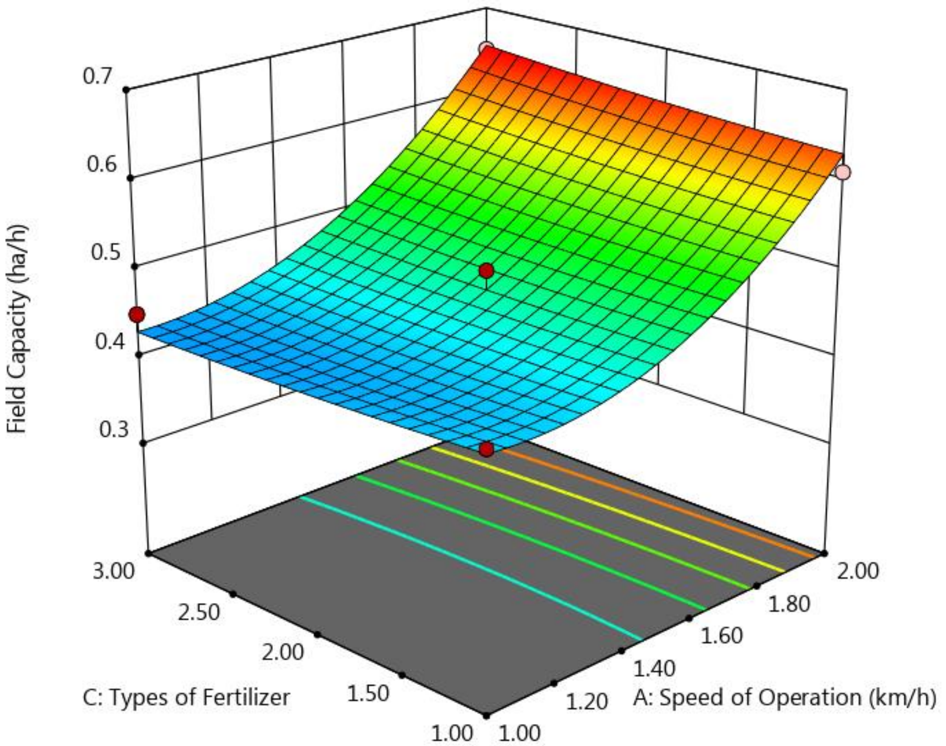


Fig. 4.6 Effect of speed of operation and types of fertilizer on the field capacity

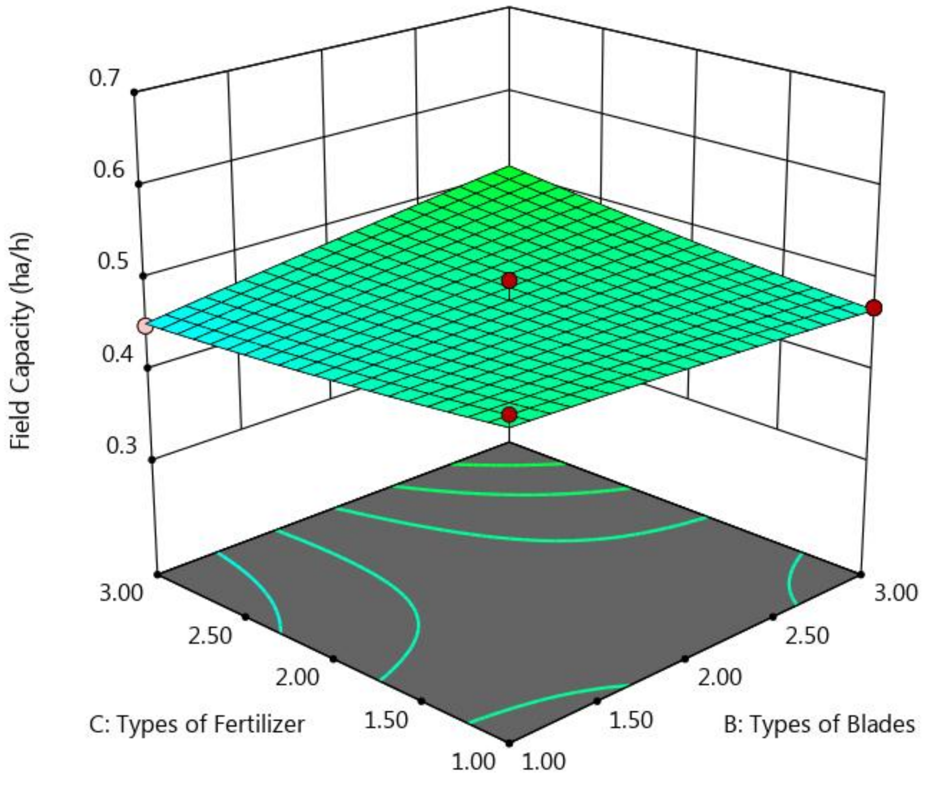


Fig. 4.7 Effect of types of blade and types of fertilizer on the field capacity

The ANOVA shown in Table 4.9 indicates that, the high value of model F (21.07) suggesting quadratic model could be successfully used to fit experimental data ($p< 0.0003$). As per F-values indicates in Table 4.9, the linear term speed of operation has a significant effect on the field capacity at 1 % level of significance. Similarly, the interaction terms speed of operation A^2 has significant effect on the field capacity at 1 % level of significance. The remaining terms of interaction and quadratic are not significant. The Lack of Fit F-value of 1.35 implies the Lack of Fit is not significant relative to the pure error. There is a 37.78 % chance that a Lack of Fit F-value this large could occur due to noise. So, Non-significant lack of fit is good. The R^2 (0.9644) for these model is good. The predicated R^2 (0.6861) for this model was also in reasonable agreement with adjusted R^2 (0.9186). Adequate Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 13.887 indicates an adequate signal.

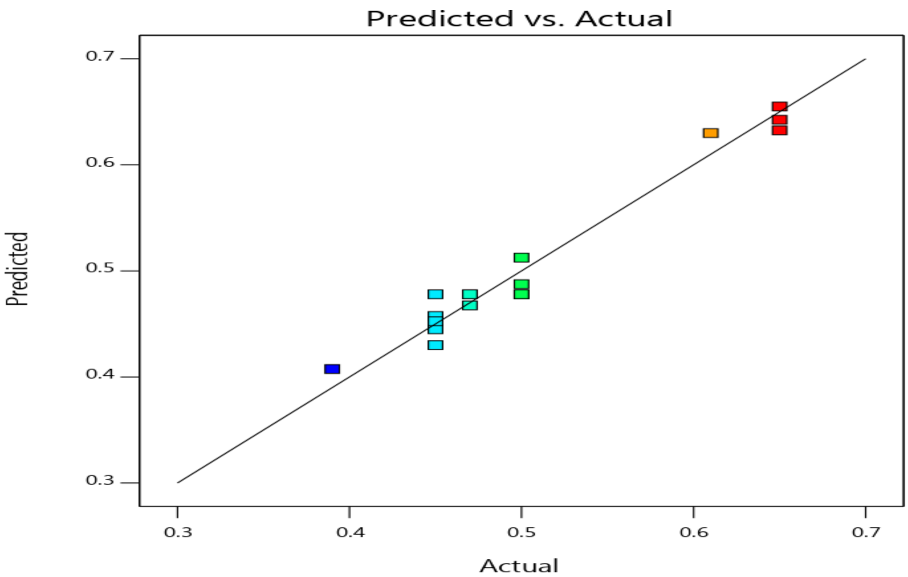


Fig. 4.8 Predicted vs Actual graph of the field capacity

The regression equation representing variation of field capacity (ha/h) with different independent parameters were fitted in quadratic form given at equation 4.1.

$$F.C. (ha/h) = +0.4780 + 0.1025 A + 0.0100 B + 0.0025 C - 0.0150 AB + 0.0100 AC + 0.0200 BC + 0.0585 A^2 + -0.0015 B^2 +0.0035 C^2 \quad \ldots (4.1)$$

$R^2 = 0.9644$

Where,

F.C. = Field capacity, ha/h

A = Speed of operation, km/h

B = Types of blades

C = Types of fertilizer

From Table 4.8, it is observed that, the increasing forward speed of operation resulted increase in field capacity. Similar results were also observed by Batta *et al*., 2015.

Table 4.9 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on field capacity at 19.91 % soil moisture content

Source	**Sum of Squares**	**df**	**Mean Square**	**Mean F-value**	**Mean p-value**	
Model	0.1024	9	0.0114	21.07	< 0.0003	Significant
A-Speed of operation	0.0840	1	0.0840	155.65	0.0001	Significant
B-Types of blades	0.0008	1	0.0008	1.48	0.2630	Not Significant
C-Types of fertilizer	0.0001	1	0.0001	0.0926	0.7698	Not Significant
AB	0.0009	1	0.0009	1.67	0.2377	Not Significant
AC	0.0004	1	0.0004	0.7407	0.4179	Not Significant
BC	0.0016	1	0.0016	2.96	0.1289	Not Significant
A^2	0.0144	1	0.0144	26.68	0.0013	Significant
B^2	9.474E-06	1	9.474E-06	0.0175	0.8984	Not Significant
C^2	0.0001	1	0.0001	0.0955	0.7663	Not Significant
Residual	0.0038	7	0.0005			
Lack of Fit	0.0019	3	0.0006	1.35	0.3778	Not Significant
Pure Error	0.0019	4	0.0005			
Cor Total	0.1062	16		21.07		
Std. deviation	0.0232					
R-Squared	0.9644					
Adj R-Squared	0.9186					
Pred R-Squared	0.6861					
Adequate Precision	13.8868					

4.5.3.1.2 Output capacity

The Fig. 4.9 indicates that, the output capacity increases with increase in speed of operation. The periphery of tree increases the output capacity of fertilizer application system. It was observed that the maximum output 5.5 kg/tree at 17.28 m periphery. This is because of large periphery of tree. A type of fertilizer, blades and does not have effect on output capacity. Fig. 4.9 shows the effect of speed of operation and types of blade on output capacity. Fig. 4.10 shows the effect of speed of operation and types of fertilizer on output capacity. Fig. 4.11 shows effect of types of blades and types of fertilizer on output capacity. It indicates that for smaller periphery tree, the output capacity was low and no effect of speed of operation and types of fertilizer on output capacity was observed.

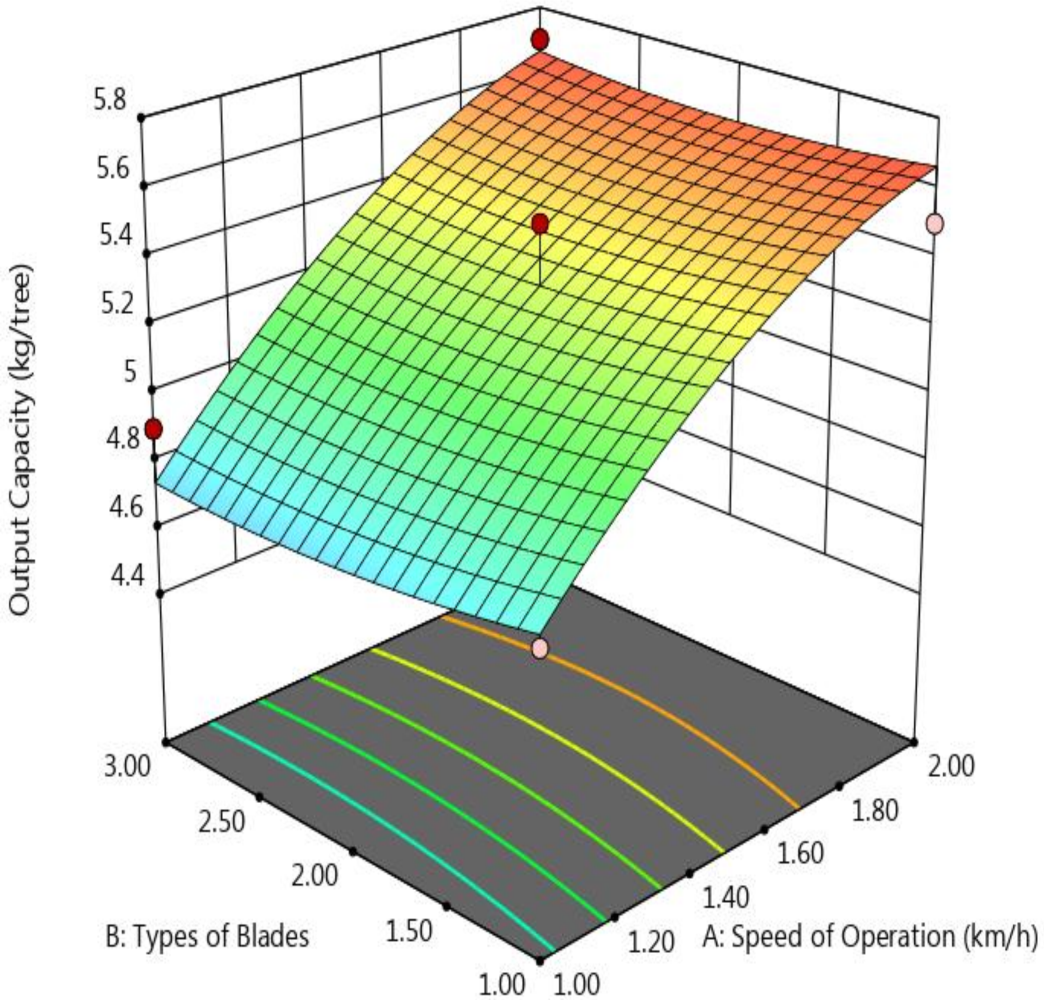


Fig. 4.9 Effect of speed of operation and types of blades on output capacity

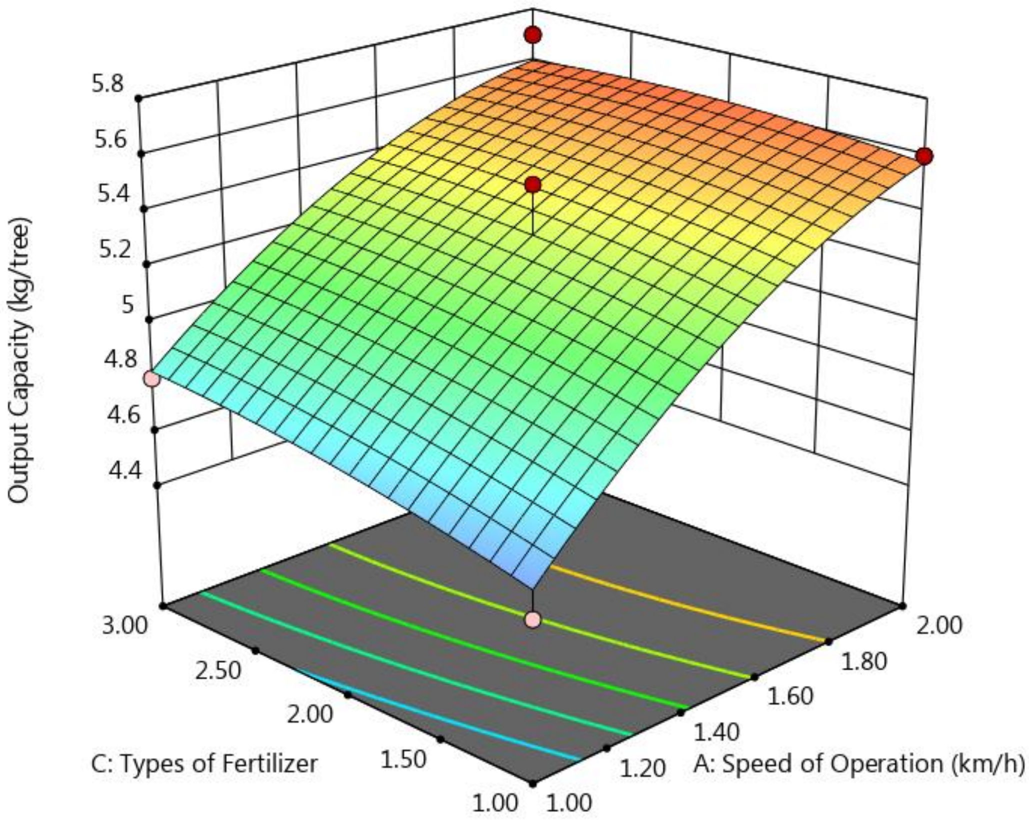


Fig. 4.10 Effect of speed of operation and types of fertilizer on output capacity

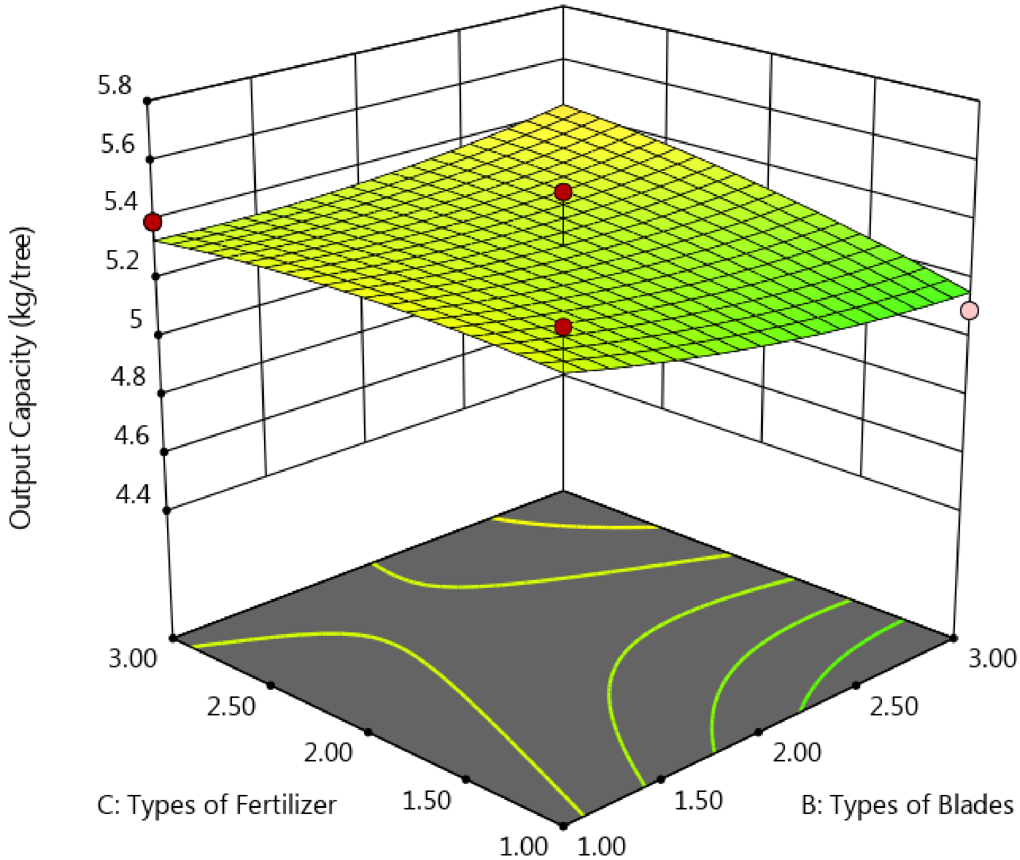


Fig. 4.11 Effect of types of blade and types of fertilizer on output capacity

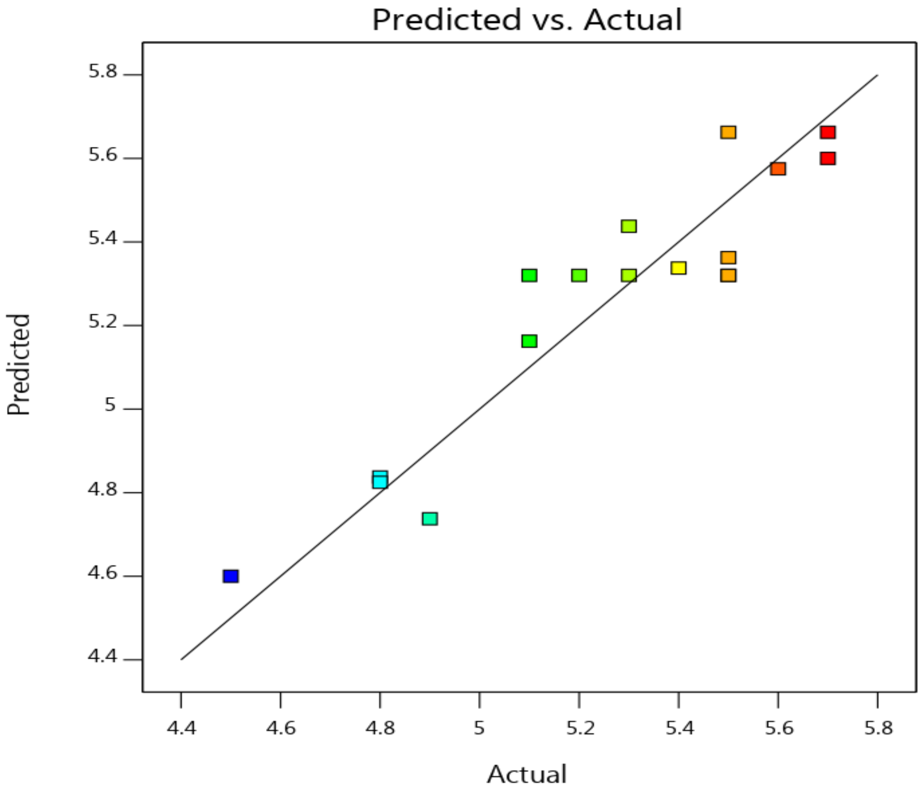


Fig. 4.12 Predicted vs Actual graph of the output capacity

The ANOVA shown in Table 4.10 indicates that, the Model F-value of 5.25 implies the model is significant. There is only a 1.99 % chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A is a significant model term. Values greater than 0.1000 indicate the model terms are not significant. The Lack of Fit F-value of 1.28 implies the Lack of Fit is not significant relative to the pure error. There is a 39.59% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good. A negative Predicted R^2 implies that the overall mean may be a better predictor of your response than the current model. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 7.323 indicates an adequate signal.

The regression equation representing variation of field output capacity (kg/tree) with different independent parameters were fitted in quadratic form given at equation 4.2.

$$\text{O.C. (kg/tree)} = +5.32 + 0.4375A - 0.0250\,B + 0.0625\,C + 0.0250AB - 0.0500\,AC - 0.0750\,BC - 0.1350\,A^2 + 0.0400\,B^2 - 0.0350\,C^2 \quad \ldots.\ (4.2)$$

$$R^2 = 0.8710$$

Where,

O.C. = Output capacity, kg/tree

A-Speed of operation, km/h

B-Types of blades

C-Types of fertilizer

Table 4.10 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on output capacity at 19.91 % soil moisture content

Source	Sum of Squares	df	Mean Square	Mean F-value	Mean p-value	
Model	1.69	9	0.1879	5.25	0.0199	Significant
A-Speed of operation	1.53	1	1.53	42.79	0.0003	Significant
B-Types of blades	0.0050	1	0.0050	0.1397	0.7196	Not Significant
C-Types of fertilizer	0.0313	1	0.0313	0.8733	0.3812	Not Significant
AB	0.0025	1	0.0025	0.0699	0.7992	Not Significant
AC	0.0100	1	0.0100	0.2794	0.6134	Not Significant
BC	0.0225	1	0.0225	0.6287	0.4538	Not Significant
A^2	0.0767	1	0.0767	2.14	0.1865	Not Significant
B^2	0.0067	1	0.0067	0.1883	0.6774	Not Significant
C^2	0.0052	1	0.0052	0.1441	0.7155	Not Significant
Residual	0.2505	7	0.0358			
Lack of Fit	0.1225	3	0.0408	1.28	0.3959	Not Significant
Pure Error	0.1280	4	0.0320			
Cor Total	1.94	16				
Std. deviation	0.1892					
R-Squared	0.8710					
Adj R-Squared	0.7050					
Pred R-Squared	-0.1127					
Adequate Precision	7.3232					

4.5.3.1.3 Fuel consumption

The Fig. 4.13 indicates that, the fuel consumption increased with increase in canopy of tree. The periphery of tree increases the fuel consumption of fertilizer application system. It is observed from Table 4.8, the fuel consumption increases with increase in periphery and vice versa. The fuel consumption depends on the size of periphery of tree and speed of operation. Fig. 4.13 shows the effect of speed of operation and types of blades on fuel consumption. It indicates that for smaller periphery tree the fuel consumption was less. Fig. 4.14 shows the effect of speed of operation and types of fertilizer on fuel consumption. Fig. 4.15 shows the effect of types of blade and types of fertilizer on fuel consumption and no effect of types of blade and types of fertilizer on fuel consumption was observed.

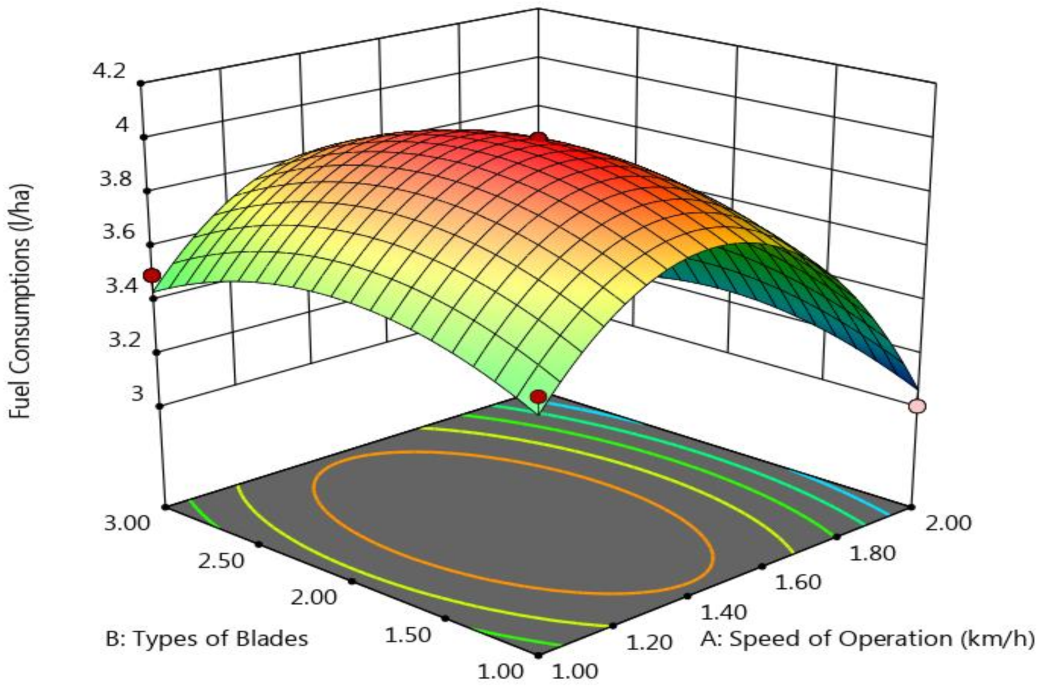


Fig. 4.13 Effect of speed of operation and types of blades on fuel consumption

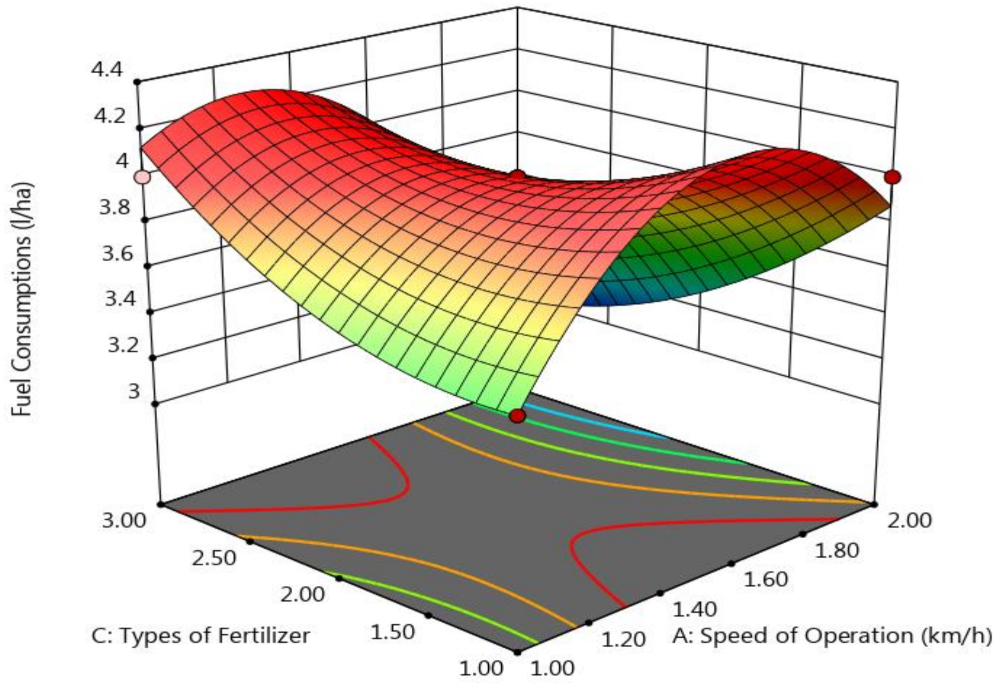


Fig. 4.14 Effect of speed of operation and types of fertilizer on fuel consumption

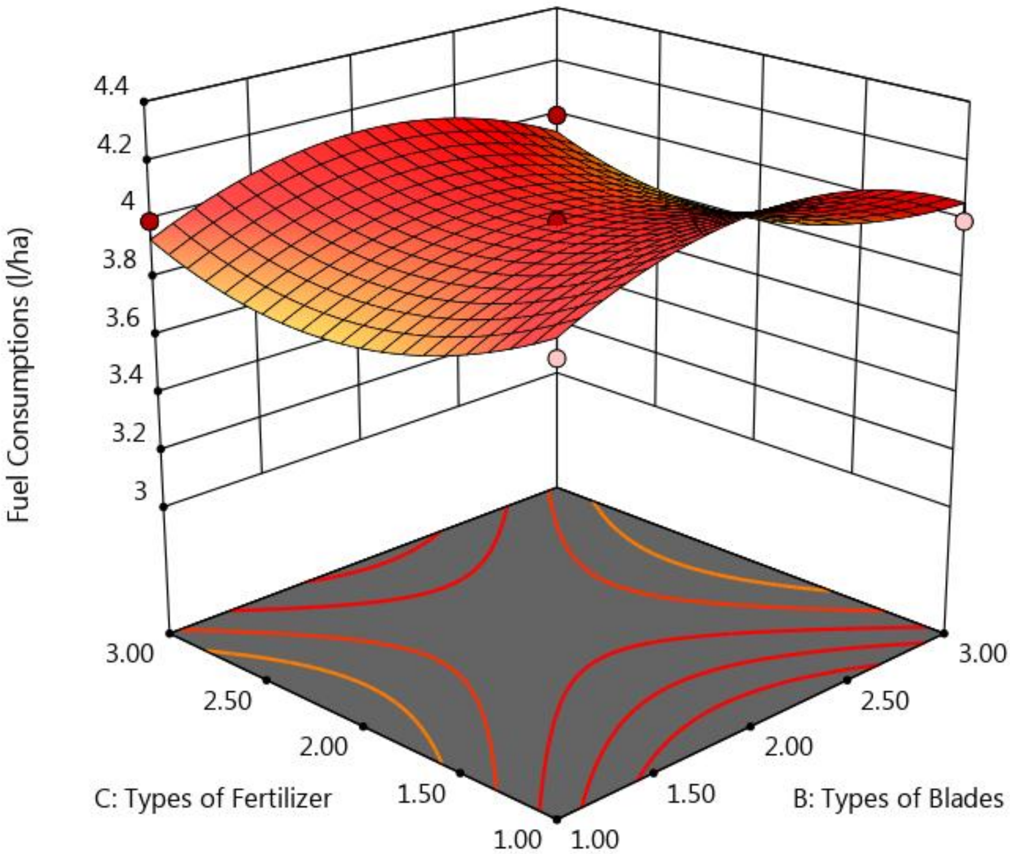


Fig. 4.15 Effect of types of blades and types of fertilizer on fuel consumption

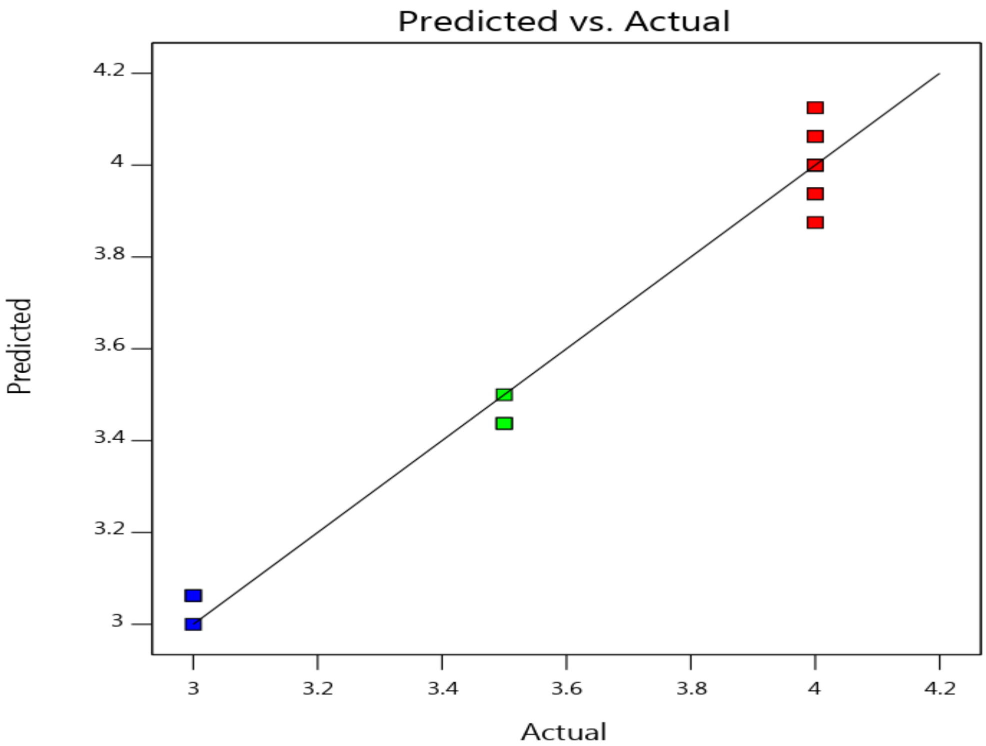


Fig. 4.16 Predicted vs Actual graph of the fuel consumptions

The ANOVA shown in Table 4.11 indicates that, The Model F-value of 31.07 implies the model is significant. There is only a 0.01 % chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, AC, A^2, B^2, C^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The Lack of Fit F-value of 0.208 implies the Lack of Fit is not significant relative to the pure error. The Predicted R^2 of 0.6092 is not as close to the Adjusted R^2 of 0.9442 as one might normally expect. This may indicate a large block effect with model. Non-significant lack of fit is good. The R^2 (0.9756) for these model is good. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 15.523 indicates an adequate signal. This model can be used to navigate the design space. Adequate Precision of the model was 15.523 indicates an adequate signal.

The regression equation representing variation of fuel consumption (l/ha) with different independent parameters were fitted in quadratic form given at equation 4.3.

$$F.C.\ (l/ha) = +4.00 - 0.1875\,A - 0.0000\,B - 0.0625\,C - 0.0000\,AB - 0.3750\,AC - 0.0000\,BC - 0.5625\,A^2 - 0.1875\,B^2 + 0.1875\,C^2 \quad \ldots (4.3)$$

$$R^2 = 0.9756$$

Where,

F. C. = Fuel consumption, l/tree

A = Speed of operation, km/h

B = Types of blades

C = Types of fertilizer

From Table 4.8, it is observed that increasing forward speed of operation increase in fuel consumption. Similar results were also observed by Batta *et al.,* 2015.

Table 4.11 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on fuel consumption at 19.91 % soil moisture content

Source	**Sum of Squares**	**df**	**Mean Square**	**Mean F-value**	**Mean p-value**	
Model	2.50	9	0.2774	31.07	< 0.0001	Significant
A-Speed of operation	0.2813	1	0.2813	31.50	0.0008	Significant
B-Types of blades	0.0000	1	0.0000	0.0000	1.0000	Not Significant
C-Types of fertilizer	0.0313	1	0.0313	3.50	0.1036	Not Significant
AB	0.0000	1	0.0000	0.0000	1.0000	Not Significant
AC	0.5625	1	0.5625	63.00	< 0.0001	Significant
BC	0.0000	1	0.0000	0.0000	1.0000	Not Significant
A^2	1.33	1	1.33	149.21	< 0.0001	Significant
B^2	0.1480	1	0.1480	16.58	0.0047	Significant
C^2	0.1480	1	0.1480	16.58	0.0047	Significant
Residual	0.0625	7	0.0089			
Lack of Fit	0.0625	3	0.0208			Not Significant
Pure Error	0.0000	4	0.0000			
Cor Total	2.56	16				
Std. deviation	0.0945					
R-Squared	0.9756					
Adj R-Squared	0.9442					
Pred R-Squared	0.6092					
Adequate Precision	15.5234					

4.5.3.1.4 Depth of ring basin

The Fig. 4.17 shows the effect of speed of operation and types of blades on depth of ring basin. It was observed that the maximum depth of ring basin 19 cm at 1.5 km/h operational speeds with hatched blade. Fig. 4.18 indicates the effect of speed of operation and types of fertilizer. The Fig. 4.19 shows that the effect of types of blade and types of fertilizer on the depth of ring basin. The types of blade and types of fertilizer do not have any effect on depth of ring basin as depth of ring basin is depends on interaction of types of blades and operational speeds.

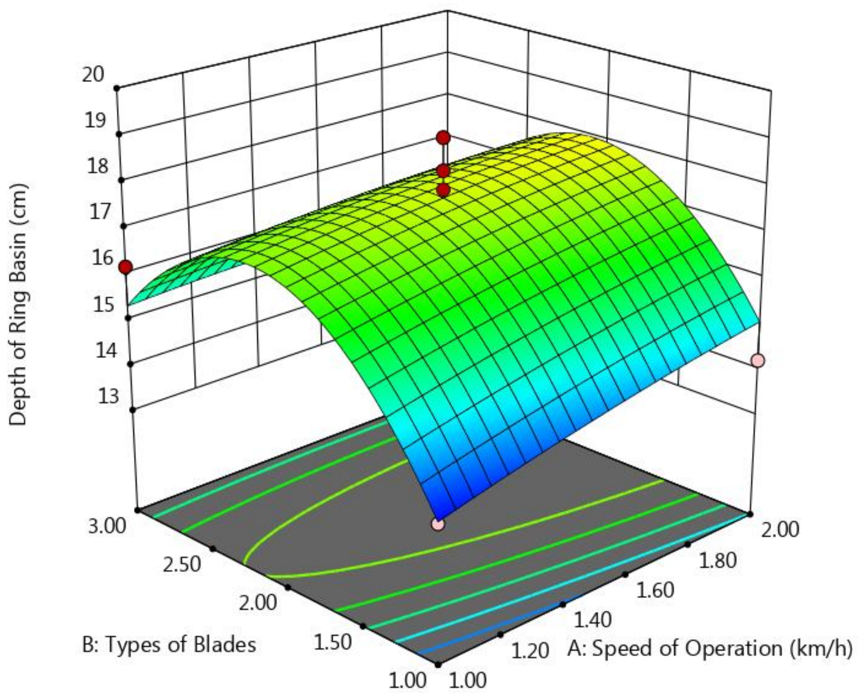


Fig. 4.17 Effect of speed of operation and types of blades on depth of ring basin

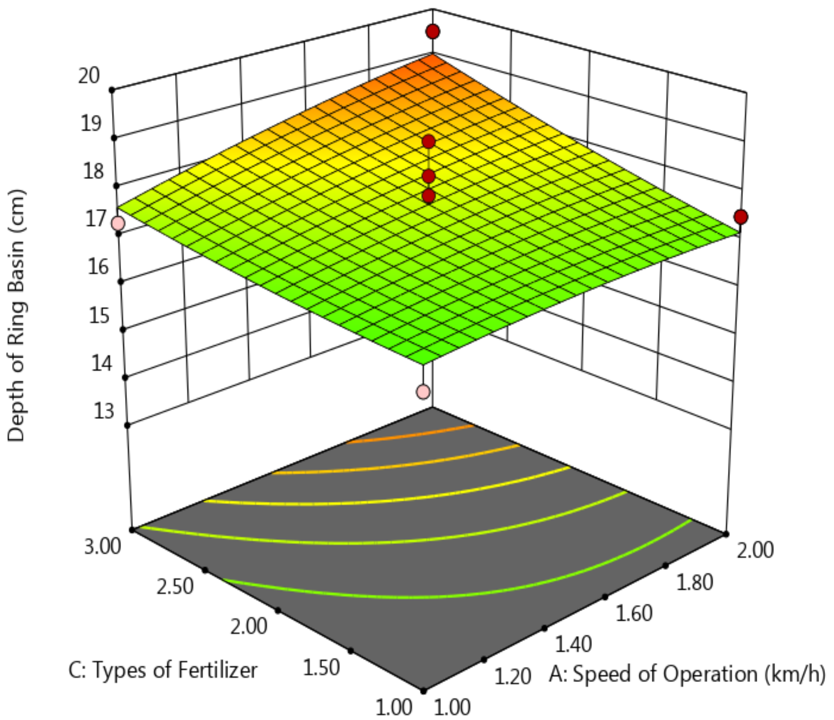


Fig.4.18 Effect of speed of operation and types of fertilizer on depth of ring basin

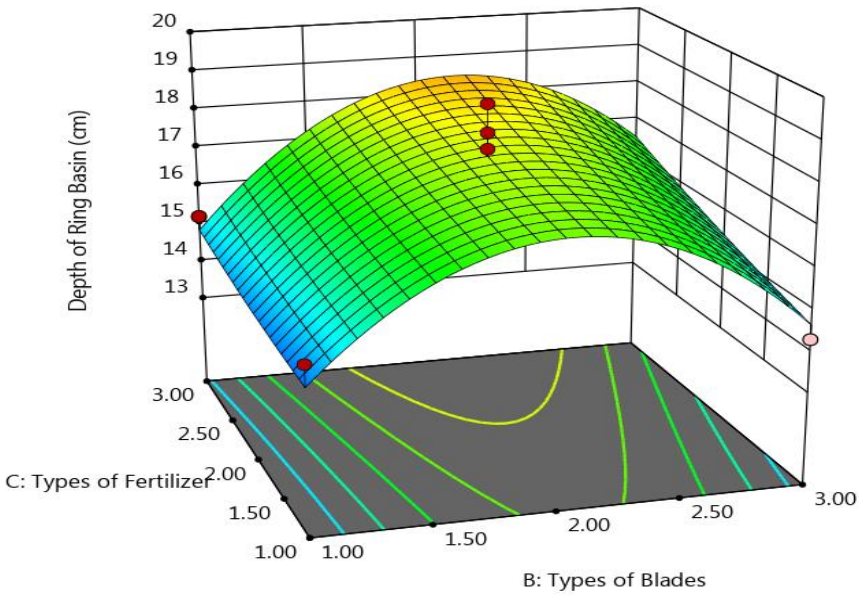


Fig. 4.19 Effect of types of blade and types of fertilizer on depth of ring basin

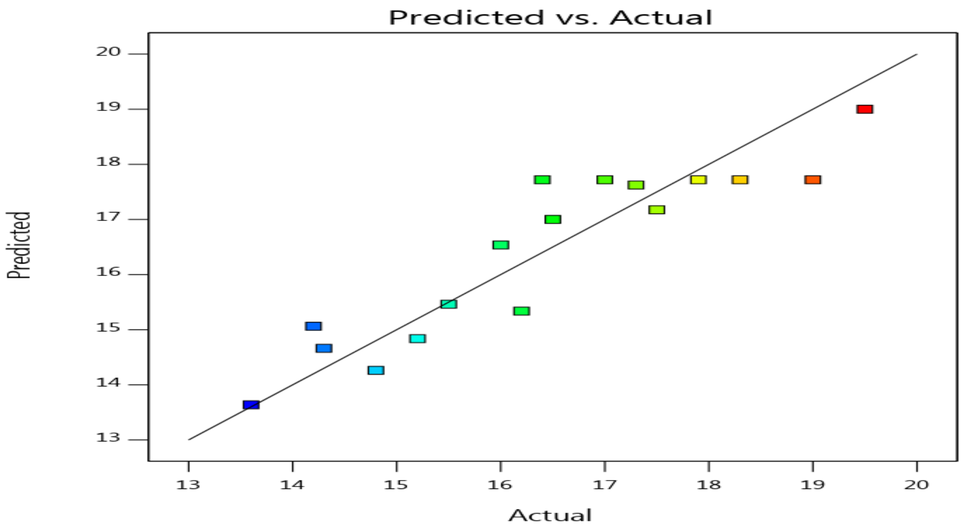


Fig. 4.20 Predicted vs Actual graph of the depth of ring basin

The ANOVA shown in Table 4.12 indicates that, The Model F-value of 4.19 implies the model is significant. There is a 3.60 % chance that an F-value this large could occur due to noise (< 0.0360). As per F-values indicates in Table 4.12, P-values < 0.0500 indicate model terms are significant. In this case B^2 is a significant model term. The Lack of Fit F-value of 0.95 implies the Lack of Fit is not significant relative to the pure error. There is a 49.64 % chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good. The R^2 (0.8435) for these model is good. The predicated R^2 is (-0.1819) for this model. A negative Predicted R^2 implies that the overall mean may be a better predictor of this model. Adequate Precision of the model was 6.8418 indicates an adequate signal.

The regression equation representing variation of depth of ring basin (cm) with different independent parameters were fitted in quadratic form given at equation 4.4.

$$\text{Depth of ring basin (cm)} = +017.72 + 0.3875\,A + 0.5250\,B + 0.6125\,C - 0.3250\,AB + 0.3000\,AC + 0.3250\,BC - 0.1100\,A^2 - 2.74\,B^2 + 0.0900\,C^2 \quad \ldots (4.4)$$

$R^2 = 0.8435$

Where,

A-Speed of operation, km/h

B-Types of blades

C-Types of fertilizer

Table 4.12 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on depth of ring basin at 19.91 % soil moisture content

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	39.40	9	4.38	4.19	< 0.0360	Significant
A-Speed of operation	1.20	1	1.20	1.15	0.3191	Not Significant
B-Types of blades	2.21	1	2.21	2.11	0.1895	Not Significant
C-Types of fertilizer	3.00	1	3.00	2.87	0.1339	Not Significant
AB	0.4225	1	0.4225	0.4046	0.5450	Not Significant
AC	0.3600	1	0.3600	0.3447	0.5756	Not Significant
BC	0.4225	1	0.4225	0.4046	0.5450	Not Significant
A^2	0.0509	1	0.0509	0.0488	0.8315	Not Significant
B^2	31.50	1	31.50	30.16	0.0009	Significant
C^2	0.0341	1	0.0341	0.0327	0.8617	Not Significant
Residual	7.31	7	1.04			
Lack of Fit	3.04	3	1.01	0.9505	0.4964	Not Significant
Pure Error	4.27	4	1.07			
Cor Total	46.71	16				
Std. deviation	1.02					
R-Squared	0.8435					
Adj R-Squared	0.6423					
Pred R-Squared	-0.1849					
Adequate Precision	6.8418					

Fig. 4.21 Measurements of depth of ring basin

Fig. 4.22 Ring basin developed by fertilizer application system

4.5.3.2 Field performance of developed fertilizer application system at 23.99 % soil moisture content

The same procedure was adopted for 23.99 % soil moisture content. The experimental run and operational responses are given in Table 4.13

Table 4.13 - Experimental design used to evaluate the effect of operational parameters on performance by RSM at 23.99 % soil moisture content

Run	Periphery, m	Speed of operation, km/h	Types of blades	Types of fertilizer	Field capacity, ha/h	Output capacity, kg/tree	Fuel consumption, l/ha	Depth of ring basin, cm
1	15.24	1.50	Hatched	16:16:16 + Urea	0.45	5.1	4.5	16.5
2	16.49	2.00	C blade	16:16:16 + Urea	0.5	4.8	5	15.8
3	12.80	2.00	Hatched	15:15:15 + Urea	0.57	4.5	5	17
4	11.23	1.00	L blade	16:16:16 + Urea	0.45	5.5	4	15.5
5	13.98	1.00	C blade	16:16:16 + Urea	0.4	5.6	4	14.5
6	14.77	1.50	Hatched	16:16:16 + Urea	0.49	5.3	4.5	16.7
7	14.69	1.00	Hatched	17:17:17 + Urea	0.4	5.6	4	17
8	11.50	2.00	Hatched	17:17:17 + Urea	0.57	4.9	5	16.5
9	17.28	1.50	Hatched	16:16:16 + Urea	0.45	5.2	4.5	17.2
10	16.42	1.50	Hatched	16:16:16 + Urea	0.45	5.3	4.5	16.5
11	15.50	1.50	L blade	15:15:15 + Urea	0.45	5.5	4.5	15.3
12	13.67	1.50	L blade	17:17:17 + Urea	0.49	5.4	4.5	16
13	16.10	1.50	C blade	15:15:15 + Urea	0.45	5.2	4.5	15.2
14	12.09	2.00	L blade	16:16:16 + Urea	0.5	4.9	4.5	15.8
15	15.71	1.00	Hatched	15:15:15 + Urea	0.38	5.8	4	18
16	11.72	1.50	Hatched	16:16:16 + Urea	0.45	5.1	4.5	16
17	13.04	1.50	C blade	17:17:17 + Urea	0.49	5.4	4.5	14.5

The Table 4.13 indicates the lower variation in depth of ring basin and field capacity compared to 19.91 % soil moisture content. These may be due to higher moisture content, soil sticks to the ridger and operational time per tree was increases result in decrease in the field capacity. Similar results were also observed by Singh *et al.,* 2018.

4.5.3.2.1 Field capacity

As mentioned in section 3.5.4.1 (B), the field capacity of fertilizer application system was determined. Table 4.13 indicates, the field capacity increases with increase in speed of operation. The ANOVA shown in Table 4.14 indicates that, The Model F-value of 3.71 implies the model is significant. There is a 4.90 % chance that an F-value this large could occur due to noise suggesting quadratic model could be successfully used to fit experimental data < 0.0490. As per F-values indicates in Table 4.14, the linear term of speed of operation have significant effect on the field capacity at 5 % level of significance. The Lack of Fit F-value of 6.54 implies the Lack of Fit is not significant relative to the pure error. There is a 5.07 % chance that a Lack of Fit F-value, this large could occur due to noise. Non-significant lack of fit is good. In this case A is a significant model term. The R^2 (0.8265) for these model is good. The predicated R^2 is (-1.3512) for this model. A negative Predicted R^2 implies that the overall mean may be a better predictor of this model. Adequate Precision of the model was 6.7965 indicates an adequate signal.

The regression equation representing variation of field capacity (ha/h) with different independent parameters were fitted in quadratic form given at equation 4.5.

$$\text{Field Capacity (ha/h)} = +\,0.4580 + 0.0638\,A + 0.0063\,B + 0.0125\,C - 0.0125\,AB - 0.0050\,AC + 0.0000\,BC + 0.0073\,A^2 - 0.0027\,B^2 + 0.0147\,C^2 \quad \ldots.\ (4.5)$$

$$R^2 = 0.8265$$

Where,

A = Speed of operation, km/h

B = Types of blades

C = Types of fertilizer

Table 4.14 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on field capacity at 23.99 % soil moisture content

Source	**Sum of Squares**	**df**	**Mean Square**	**Mean F-value**	**Mean p-value**	
Model	0.0360	9	0.0040	3.71	0.0490	Significant
A-Speed of operation	0.0325	1	0.0325	30.12	0.0009	Significant
B-Types of blades	0.0003	1	0.0003	0.2895	0.6072	Not Significant
C-Types of fertilizer	0.0012	1	0.0012	1.16	0.3175	Not Significant
AB	0.0006	1	0.0006	0.5791	0.4715	Not Significant
AC	0.0001	1	0.0001	0.0927	0.7697	Not Significant
BC	0.0000	1	0.0000	0.0000	1.0000	Not Significant
A^2	0.0002	1	0.0002	0.2051	0.6644	Not Significant
B^2	0.0000	1	0.0000	0.0295	0.8685	Not Significant
C^2	0.0009	1	0.0009	0.8488	0.3876	Not Significant
Residual	0.0076	7	0.0011			
Lack of Fit	0.0063	3	0.0021	6.54	0.0507	Not Significant
Pure Error	0.0013	4	0.0003			
Cor Total	0.0436	16				
Std. deviation						0.0329
R-Squared						0.8265
Adj R-Squared						0.6035
Pred R-Squared						-1.3512
Adequate Precision						6.7965

4.5.3.2.2 Output capacity

As mentioned in section 3.5.4.3, the field capacity of fertilizer application system was determined. Table 4.13 indicates, the field capacity increases with increase in canopy of tree. The ANOVA shown in Table 4.15 indicates that, the Model F-value of 13.43 implies the model is significant. There is only a 0.12 % chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, AC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The Lack of Fit F-value of 1.92 implies the Lack of Fit is not significant relative to the pure error. There is a 26.84 % chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good. The R^2 for this model is (0.9453). The predicated R^2 is (0.4484) for this model. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 12.704 indicates an adequate signal. This model can be used to navigate the design space.

The regression equation representing variation of output capacity (kg/tree) with different independent parameters were fitted in quadratic form given at equation 4.6.

$$\text{Output Capacity (kg/tree)} = +5.20 - 0.4250\,A + 0.0375\,B - 0.0375\,C + 0.0500\,AB + 0.1500\,AC - 0.0750\,BC - 0.0875\,A^2 + 0.0875B^2 + 0.0875\,C^2 \quad \text{…. (4.6)}$$

$$R^2 = 0.9453$$

Where,

A = Speed of operation, km/h

B = Types of blades

C = Types of fertilizer

Table 4.15 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on output capacity at 23.99 % soil moisture content

Source	**Sum of Squares**	**df**	**Mean Square**	**Mean F-value**	**Mean p-value**	
Model	1.68	9	0.1871	13.43	0.0012	Significant
A-Speed of Operation	1.45	1	1.45	103.74	< 0.0001	Significant
B-Types of Blades	0.0112	1	0.0112	0.8077	0.3987	Not Significant
C-Types of Fertilizer	0.0112	1	0.0112	0.8077	0.3987	Not Significant
AB	0.0100	1	0.0100	0.7179	0.4248	Not Significant
AC	0.0900	1	0.0900	6.46	0.0386	Significant
BC	0.0225	1	0.0225	1.62	0.2443	Not Significant
A^2	0.0322	1	0.0322	2.31	0.1720	Not Significant
B^2	0.0322	1	0.0322	2.31	0.1720	Not Significant
C^2	0.0322	1	0.0322	2.31	0.1720	Not Significant
Residual	0.0975	7	0.0139			
Lack of Fit	0.0575	3	0.0192	1.92	0.2684	Not Significant
Pure Error	0.0400	4	0.0100			
Cor Total	1.78	16				
Std. deviation	0.1180					
R-Squared	0.9453					
Adj R-Squared	0.8749					
Pred R-Squared	0.4484					
Adequate Precision	12.7048					

4.5.3.2.3 Fuel consumption

As mentioned in section 3.5.4.4, the fuel consumption of fertilizer application system was determined. Table 4.13 indicates, the fuel consumption increases with increase in canopy of tree. The ANOVA shown in Table 4.16 indicates that, The Model F-value of 20.82 implies the model is significant. There is only a 0.03% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The Lack of Fit F-value of 0.0208 implies the Lack of Fit is not significant relative to the pure error. Non-significant lack of fit is good. The R^2 for this model is (0.9640). The Predicted R^2 of 0.4237 is not as close to the Adjusted R^2 of 0.9177 as one might normally expect. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 15.523 indicates an adequate signal. This model can be used to navigate the design space.

The regression equation representing variation of fuel consumption (lit/tree) with different independent parameters were fitted in quadratic form given at equation 4.7.

$$\text{Fuel Consumption (l/ha)} = +4.50 + 0.4375A - 0.0625B - 0.0000C - 0.1250AB + 0.0000AC + 0.0000BC - 0.0625A^2 - 0.0625B^2 + 0.0625C^2 \quad \ldots (4.7)$$

$$R^2 = 0.9640$$

Where,

A = Speed of operation, km/h

B = Types of blades

C = Types of fertilizer

Table 4.16 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on fuel consumption at 23.99 % soil moisture content

Source	**Sum of Squares**	**df**	**Mean Square**	**Mean F-value**	**Mean p-value**	
Model	1.67	9	0.1859	20.82	0.0003	Significant
A-Speed of operation	1.53	1	1.53	171.50	0.0001	Significant
B-Types of blades	0.0313	1	0.0313	3.50	0.1036	Not Significant
C-Types of fertilizer	0.0000	1	0.0000	0.0000	1.0000	Not Significant
AB	0.0625	1	0.0625	7.00	0.0331	Significant
AC	0.0000	1	0.0000	0.0000	1.0000	Not Significant
BC	0.0000	1	0.0000	0.0000	1.0000	Not Significant
A^2	0.0164	1	0.0164	1.84	0.2168	Not Significant
B^2	0.0164	1	0.0164	1.84	0.2168	Not Significant
C^2	0.0164	1	0.0164	1.84	0.2168	Not Significant
Residual	0.0625	7	0.0089			
Lack of Fit	0.0625	3	0.0208			Not Significant
Pure Error	0.0000	4	0.0000			
Cor Total	1.74	16				
Std. deviation	0.0945					
R-Squared	0.9640					
Adj R-Squared	0.9177					
Pred R-Squared	0.4237					
Adequate Precision	15.5234					

4.5.3.2.4 Depth of ring basin

As mentioned in section 3.5.4.5, the depth of ring basin of fertilizer application system was determined. The ANOVA shown in Table 4.17 indicates that, The Model F-value of 4.15 implies the model is significant. There is 3.71 % chance that an F-value this large could occur due to noise. As per F-values indicates in Table 4.15, P-values < 0.0500 indicate model terms are significant. In this case B^2 is a significant model term. Values greater than 0.1000 indicate the model terms are not significant. The Lack of Fit F-value of 2.72 implies the Lack of Fit is not significant relative to the pure error. There is a 17.88 % chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good. The R^2 (0.8420) for these model is good. The predicated R^2 is (-0.7778) for this model. A negative Predicted R^2 implies that the overall mean may be a better predictor of this model. Adequate Precision of the model was 6.9463 indicates an adequate signal.

The regression equation representing variation of depth of ring basin (cm) with different independent parameters were fitted in polynomial form given at equation 4.8.

$$\text{Depth of ring basin (cm)} = +16.58 + 0.0125\,A + 0.3250\,B - 0.1875\,C - 0.2500\,AB + 0.1250\,AC + 0.3500\,BC + 0.3475\,A^2 - 1.53\,B^2 + 0.1975\,C^2$$

$$R^2 = 0.8420 \qquad \text{…. (4.8)}$$

Where,
A = Speed of operation, km/h

B = Types of blades

C = Types of fertilizer

Table 4.17 ANOVA for study of effect of speed of operation, types of blades and types of fertilizer on depth of ring basin at 23.99 % soil moisture content

Source	**Sum of Squares**	**df**	**Mean Square**	**Mean F-value**	**Mean p-value**	
Model	12.13	9	1.35	4.15	0.0371	Significant
A-Speed of operation	0.0012	1	0.0012	0.0038	0.9523	Not Significant
B-Types of blades	0.8450	1	0.8450	2.60	0.1509	Not Significant
C-Types of fertilizer	0.2813	1	0.2813	0.8652	0.3832	Not Significant
AB	0.2500	1	0.2500	0.7691	0.4096	Not Significant
AC	0.0625	1	0.0625	0.1923	0.6743	Not Significant
BC	0.4900	1	0.4900	1.51	0.2592	Not Significant
A^2	0.5084	1	0.5084	1.56	0.2512	Not Significant
B^2	9.82	1	9.82	30.22	0.0009	Significant
C^2	0.1642	1	0.1642	0.5052	0.5002	Not Significant
Residual	2.28	7	0.3251			
Lack of Fit	1.53	3	0.5092	2.72	0.1788	Not Significant
Pure Error	0.7480	4	0.1870			
Cor Total	14.40	16				
Std. deviation						0.5702
R-Squared						0.8420
Adj R-Squared						0.6389
Pred R-Squared						-0.7778
Adequate Precision						6.9463

4.6 Numerical Optimization of operational parameters of developed fertilizer application system

The performance of fertilizer application system was evaluated as per standard procedure and statistical experiments. The numerical multi-response optimizing technique was used by ‘Design Expert 11’ software. Selected combinations of parameters for optimized values i.e. speed of operation, types of blade and types of fertilizer are in range, field capacity be maximum, output capacity be range, fuel consumption be minimum and depth of ring basin be range. The optimized combinations of selected operating parameters of fertilizer application system by using Response surface method is shown in Fig. 4.23 and Fig.4.24 at 19.91 and 23.99 % soil moisture content. The optimized value of various parameters for fertilizer application system predicted by software is shown in Table 4.18.

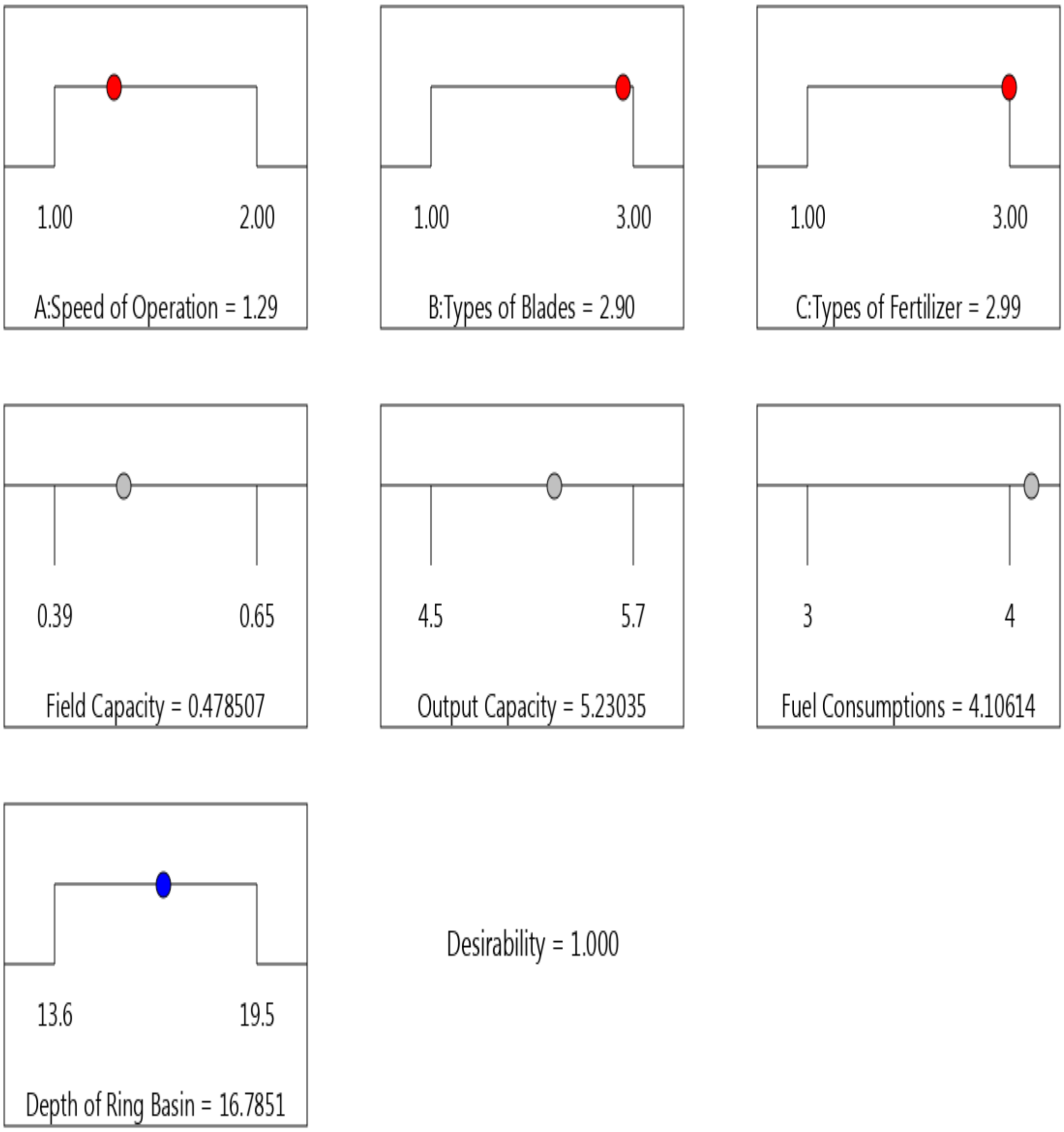


Fig. 4.23 Numerical optimized combinations of selected operating parameter of fertilizer application system by using RSM at 19.91 % soil moisture content

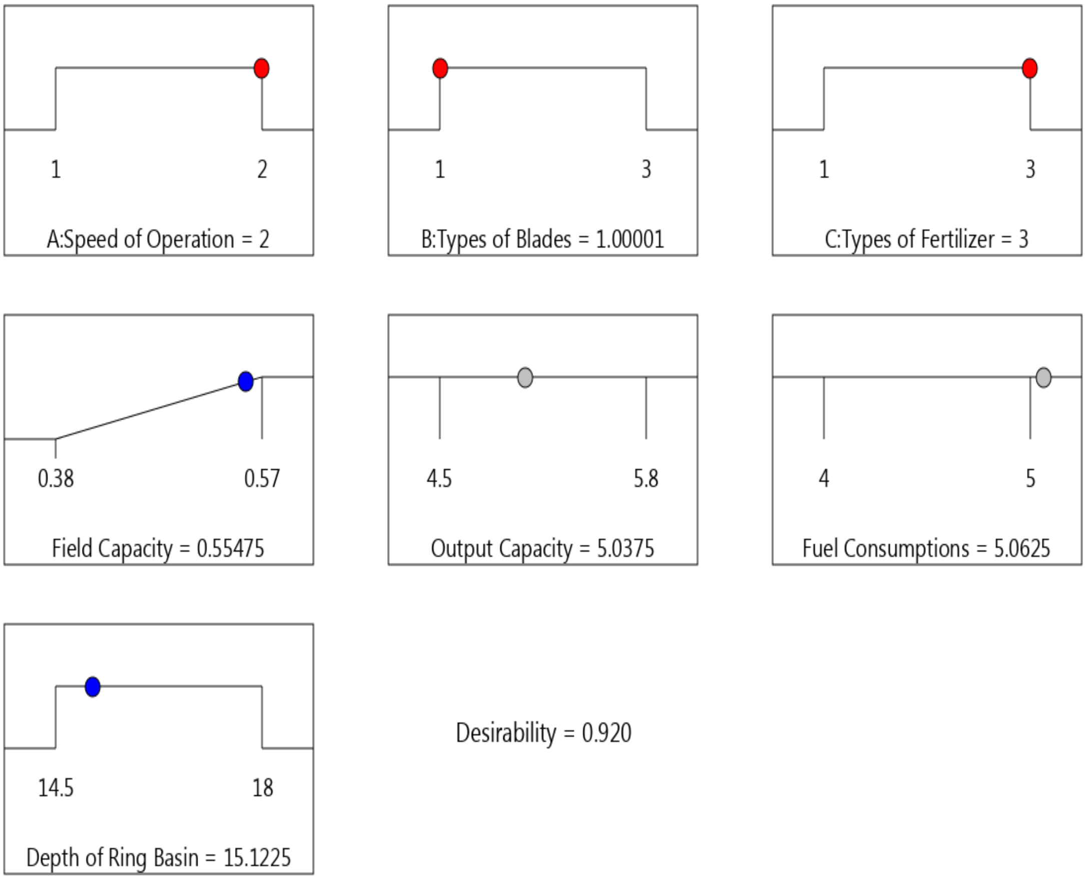


Fig. 4.24 Numerical optimized combinations of selected operating parameter of fertilizer application system by using RSM at 23.99 % soil moisture content

Table 4.18 Optimization of selected parameter by using Response surface method

	Periphery, m	**Speed of operation, km/h**	**Types of blade**	**Types of fertilizer**	**Field capacity, ha/h**	**Output capacity, kg/tree**	**Fuel consumption, lit/ha**	**Depth of ring basin, cm**
At 19.91 % soil moisture content								
Predicted value	-	1.29 ≈ 1.5	2.90 ≈ 3	2.99 ≈ 3	0.47	5.23	4.10	16.78
Observed value	12.5	1.5	3	3	0.51	5.1	4	16.2
At 23.99 % soil moisture content								
Predicted /obtained value	-	2	1.0	3	0.55	5.03	5.06	15.12
Observed / obtained value	13.08	2	1	3	0.49	5.3	4.5	14.8

Based on the predictions, the fertilizer application system was tested at particular predicted values and performance of fertilizer application system was observed. By comparing predicted and observed values, not much variation in predicted and observed value for the performance of fertilizer application system was found, which indicates, the optimized operating parameters was fairly predicting the performance of fertilizer application system by Design Expert 11 software. To get better performance of fertilizer application system needs to operate at speed of operation 1.5 and 2 km/h speed with L and C blade and 17:17:17 fertilizer at 19.91 % and 23.99 % soil moisture content, respectively.

4.7 Overall performance of developed fertilizer application system

The overall performance of fertilizer application system at different speeds, type of blades and type of fertilizers were analysed and presented in Table 4.19.

Table 4.19 Overall performance of developed fertilizer application system

Sr. No	**Particulars**	**Soil moisture content, %**	
		19.91	**23.99**
1.	**Field capacity, ha/h**		
	1 km/h	0.43	0.4
	1.5 km/h	0.47	0.46
	2 km/h	0.64	0.53
2.	**Field efficiency, %**		
	1 km/h	0.53	0.5
	1.5 km/h	0.48	0.47
	2 km/h	0.49	0.41
3.	**Output capacity of Vermicompost, kg/ha**		
	42.20 % M.C.	2480	-
	47.05 % M.C	-	2905
4.	**Output capacity of fertilizer, kg/ha**		
	15:15:15 + Urea	517	525
	16:16:16 + Urea	527	520
	17:17:17 + Urea	530	532
5.	**Fuel consumption, l/ha**	3 - 4	4 – 5
6.	**Depth of ring basin, cm**		
	C blade	15.4	14.9
	Hatched blade	17.7	16.8
	L blade	15.5	15.2

The output capacity for Vermicompost at 42.20 and 47.05 % moisture content was found to be 2480 and 2901 kg/ha, respectively. The fertilizer output capacity for (15:15:15 +urea), (16:16:16 + urea) and (17:17:17 + Urea) was 517, 527 and 530 and 525, 520 and 532 kg/ha at 19.91 and 23.99 % soil moisture content, respectively. The output capacity for application of Vermicompost and fertilizer varies with periphery. Lower effect was observed with speed of operation. The variation in Vermicompost rate is due to variation in the moisture content. The average fuel consumption per ha ranges from 3 to 5.0 l/ha depends upon the canopy of the tree and the speed of operations. As higher periphery of canopy, more time is required for coverage. The fuel consumption range is higher as variation in periphery of canopy is higher. The average field capacity and field efficiency of the fertilizer application system was found to be 0.42, 0.47 and 0.58 ha/h and 52.5, 48.5 and 44.96 % at 1, 1.5 and 2 km/h. The average depth of Vermicompost and fertilizer in the ring with L, C and Hatched type blades were, 15.5, 15.4 and 17.7 and 15.2, 14.9 and 16.8 cm at 19.91 and 23.99 % soil moisture content respectively. The lower variation in depth of ring basin at 23.99 % soil moisture content may be due to higher moisture content, soil sticks to ridger. The cost of operation fertilizer application is Rs. 1279/ha. The developed power weeder operated fertilizer application system saves 83 % time and 36 % cost as compare traditional method. The developed fertilizer application system works satisfactorily in the field for simultaneous application of Vermicompost and fertilizer in the ring for Mango orchards.

4.8 Cost of operation

The cost of the developed machine was found to be Rs. 8727. The cost of operation of the developed fertilizer application system was calculated and presented in Appendix-H. The costs of operation of Vermicompost and fertilizer application by developed power weeder operated fertilizer application system are presented in Table 4.20. The traditional method of fertilizer application is slow, labour intensive, drudgeries and higher cost involves in operations. The developed power weeder operated fertilizer application system saves 83 % time and 36 % cost as compared to traditional method.

Table 4.20 Cost of operation of Vermicompost and fertilizer application in mango orchard

Sr. No.	Particulars	Traditional methods	Developed fertilizer application system
1.	Labour required, man days/ha	10	1
2.	Time required, man hours/ha	30	05
3.	Cost of operation	Rs. 2000/ha	Rs. 1279/ha

CHAPTER V

SUMMARY AND CONCLUSIONS

Mango (*Mangifera Indica L.)* is known the world over as a fruit with many nutritional qualities, as it is rich in minerals, fiber, vitamins and provitamins. Mango is the most important tropical fruit of the world. Mango trees though planted at the same time in an orchard resulted in different sizes of canopy and growth rate. Appropriate nutrient management is one the most important aspect of mango production technology. The inadequate supply of nutrients, as well as overdoses of nutrients, may be harmful to obtaining more yield as well better quality of mango. Application of nutrients should be according to its year yield and canopy size. Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli recommended dose of fertilizer for a tree age of 10 to 20 years giving fruit yield up to 300 fruits is 50 kg organic manure or 25 kg Vermicompost + 1.5 kg N + 0.5 kg P_2O_5 + 0.5 kg K_2O. The application needs to be done at the onset of monsoon or if irrigation is available immediately after harvest. It is applied by digging a ring at an equal distance from the center of the trunk and edge of the canopy with pick axe and spade. A ring should be 20 cm deep and 30 cm wide. Till date, machinery is not available to dig the ring below the canopy and apply the fertilizer in the ring. Due to the unevenness of the application, there is a loss of nutrients from applied fertilizer. Fertilizer ring basin making and fertilizer application are labouries, drudgery involved work and time-consuming. To overcome the above problem, the development of a suitable fertilizer application system for mango orchards is the need of time. Hence to reduce the cost, work stress and drudgery and need for a fertilizer application the study on "Development and evaluation of fertilizer application system for mango orchards" is undertaken with the following objectives:

1. To study different methods used for weeding, fertilizer ring basin and fertilizer application system for mango orchards
2. To develop fertilizer application system for mango orchards
3. To evaluate the performance of developed fertilizer application system for mango orchards

Based on the agronomic requirement of mango crops and design consideration the power weeder-operated fertilizer application system for mango orchards was developed. The developed fertilizer application system for mango orchards consists of Vermicompost and fertilizer hopper, orifice type metering mechanism for

Vermicompost, slider plate, agitator, fertilizer metering mechanism; drive wheel, power cut-off device, ridger, furrow opener and soil covering device. The shape of Vermicompost and fertilizer hopper was trapezoidal for the free flow of Vermicompost and fertilizer. The angle of inclination of 40˚ and 42.5˚ is made with the horizontal with the capacity of 55 kg and 25 kg for Vermicompost and fertilizer respectively. For metering of Vermicompost adjustable orifice with agitator type metering mechanism was used. There are three openings of 40 mm are provided at the bottom of the Vermicompost hopper and the materials meters from these holes were collected in the Vermicompost secondary hopper placed just below the main hopper. The fertilizer hopper was mounted behind it. A plastic vertical cup type rotor with grooves on its periphery metering mechanism was used for fertilizer metering. Grooves were provided on the periphery of the plastic rotor of thickness 14 mm. The Vermicompost rate varies between 24.80 to 29.01 kg/tree, and the fertilizer rate varies between 5.17 to 5.32 kg/tree depends upon the canopy of tree. The metering mechanism was actuated by the drive wheel which transmits power through chain and sprocket.

A clutch was provided to the drive wheel so that the power can be cut off from the metering mechanism during moving from one tree to another tree and transporting. Metal tubes of 100 mm diameter and 3 mm thick used to convey Vermicompost from orifice to ridger by gravity and polythene tube of 50 mm diameter and 2 mm thick were used to convey fertilizer from fertilizer secondary hopper to furrow opener. Ridger and furrow opener was used to place the Vermicompost and fertilizer at the desired depth. A ridger was used to digging a ring and place the Vermicompost at a depth of 10 - 20 cm. Shovel type furrow opener with a rake angle of 33˚ was used to place the fertilizer just behind the ridger in a ridge. A provision was made to change the depth by adjusting nuts and bolts. The width of the ring basin varies between 20-30 cm and depth can be adjustable to 10-20 cm as per field conditions. At the backside of the frame, a V-type bund former like soil covering device was attached. The handle of the power weeder was kept free for easy turning and operation below the canopy of the tree. An adjustable single-point hitch was fabricated. Hitching is provided with two adjustable nuts and bolts which were provided limit for the lateral movement of fertilizer application system.

The developed power weeder-operated fertilizer application system for mango orchards was tested in the laboratory for the calibration of Vermicompost and fertilizer. The physical properties of Vermicompost and fertilizer were determined. The average bulk density and angle of repose for Vermicompost was 788.93, 799.30 and 802.07 kg/m^3 and 31.48°, 32.73°and 30.31° at 36.38, 42.20 and 47.05 % moisture content respectively. The average bulk density and angle of repose for Urea and 15:15:15, 16:16:16 and 17:17:17 fertilizer was 1065, 1080,1115 and 1072 kg/m^3 and 36.08°, 37.87°, 35.43° and 39.34° respectively.

The field testing of developed power weeder operated fertilizer application system for mango orchards was carried out at the Mango field Tansa farm, Dist. Palghar. To evaluate the developed fertilizer application system well-tilled loose soil and soil moisture around field capacity is required in the mango field. If soil is dry, irrigate the periphery of the mango tree and allow field to friable field condition. The weeder with rotory blade operated in 2-3 times around a mango tree. After preparing the field, a developed fertilizer application system was attached to weeder and operated in the field. The operational pattern of fertilizer application was a continuous turn below the mango canopy for digging the circular ring and applying fertilizer in the basin. The developed fertilizer application system was tested at 3/4 and full opening position of the orifice for Vermicompost with three different speeds, three different blades and three different chemical fertilizers for evaluation of field capacity, field efficiency, fuel consumption and depth of ring basin. The 'Design Expert 11' software was used for the analysis. Based on combinations suggested by Design expert software, 17 experiments were carried out at 19.91 % and 23.99 % soil moisture. The results obtained were analyzed by ANOVA to verify the significance of the effect of independent parameters on response parameters.

The output capacity for Vermicompost at 42.20 and 47.05 % moisture content was found to be 2480 and 2901 kg/ha respectively and fertilizer (15:15:15 +urea), (16:16:16 + urea) and (17:17:17 + Urea) was 517, 527 and 530 and 525, 520 and 532 kg/ha at 19.91 and 23.99 % soil moisture content respectively. The output capacity for application of Vermicompost and fertilizer varies with periphery of tree. Lower effect observed with speed of operation. The variation in Vermicompost rate is due to variation in the moisture content. The average fuel consumption per ha ranges from 3 to 5 l/ha depends upon the canopy of the tree and the speed of operations. As higher periphery of canopy, more time is required for coverage. The fuel consumption range is higher as variation in periphery of canopy is higher. The average field capacity and field efficiency of the fertilizer application system was found to be 0.42, 0.47 and 0.58 ha/h and 52.5, 48.5 and 44.96 % at 1, 1.5 and 2 km/h. The average depth of Vermicompost and fertilizer in the ring with L, C and Hatched type blades were, 15.5, 15.4 and 17.7 and 15.2, 14.9 and 16.8 cm at 19.91 and 23.99 % soil moisture content respectively. The lower variation in depth of ring basin at 23.99 % soil moisture content may be due to higher moisture content, soil sticks to ridger. The cost of operation fertilizer application is Rs. 1279/ha. The following conclusions are drawn from the study.

Conclusions

1. The developed fertilizer application system for mango orchards works satisfactorily in the field for application of Vermicompost and fertilizer rate.
2. The Vermicompost rates at moisture content 42.20 and 47.05 % was 2480 and 2901 kg/ha, respectively and fertilizer rate of (15:15:15 +urea), (16:16:16 + urea) and (17:17:17 + Urea) were 521, 523 and 531 kg/ha, respectively.
3. The field capacity of fertilizer application system was 0.42, 0.47 and 0.58 ha/h at 1, 1.5 and 2 km/h operational speeds, respectively.
4. The field efficiency of fertilizer application system was 52.5, 48.45 and 44.96 % at 1, 1.5 and 2 km/h operational speeds, respectively.
5. The average depth of Vermicompost and fertilizer in the ridge with L, C and Hatched type blades were, 15.5, 15.4 and 17.7 and 15.2, 14.9 and 16.8 cm at 19.91 and 23.99 % soil moisture content, respectively.
6. The average fuel consumption per ha ranges from 3 to 5 l/ha depends upon canopy of the tree and speed of operations.
7. The cost of operation fertilizer application is Rs. 1279/ha. The developed power weeder operated fertilizer application system saves 83 % time and 36 % cost as compared to traditional method.

Thus, the developed power weeder-operated fertilizer application system was found effective for digging the ring and applying both organic and inorganic fertilizer simultaneously in the ring in Konkan region for Mango orchards. The performance of the fertilizer application system was satisfactory for working in tilled soil with proper moisture conditions.

SUGGESTIONS FOR FUTURE RESEARCH WORK

The following suggestions are given for future research related to present study.

1. The machine needs vigorous testing on different soil types for an understanding of problems and their rectification.
2. The fertilizer application system may be tested for high-density population orchards.
3. The fertilizer application system may be tested for band applications in other orchards.
4. The transport wheel for transportation may be provided to reduce transportations time.
5. The different shape of the cross-section of the hopper and the shape of the orifice for the Vermicompost may be tried.

CHAPTER VI

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APPENDICES

APPENDIX – A

Data sheet for survey of different methods adopted by farmers for weeding, fertilizer application and fertilizer ring basin for Mango orchard

Date: **Place:**

I. **Description of field**

1. Farmer Name:
2. Name of the village:
3. Area of the field:
4. Shape of field:
5. Irrigation facilities:
6. Variety of trees:
7. Age of tree:
8. Row to row spacing:
9. Plant to plant spacing:
10. No of trees:
11. Practices adopted for harvesting:
12. Yield:

II. Methods adopted by farmer for weeding or cleaning mango orchard

1. Manual methods:
2. Mechanical Methods or machines:
3. Any other methods:

III. Methods adopted by farmer for fertilizer application

1. Time of fertilizer application:
2. Time of spraying:
3. Types of Organic manure and Chemical fertilizer used for application:
4. Quantity of Organic manure applied by farmer:
5. Quantity of Chemical fertilizer applied by farmer:
6. Labour required for application of fertilizer:
7. Time required for application of fertilizer:
8. Labour required for spraying:
9. Time required for spraying:
10. Cost of fertilizer application:
11. Cost of spraying:

12. Any other methods:

IV. Methods adopted by farmer for digging ring basin

1. Manual methods:
2. Mechanical methods:
3. Any other

APPENDIX-B

Table B - 1 Cultural practices adopted by Mango growing farmers for weeding, fertilizer application and ring basin making

Sr. No.	1	2	3	4	5
I. Description of field					
Farmer Name	Vishwas Kelakar	Mahesh Kelakar	Manoj Kelakar	Prabhakar Dandekar	Mahesh Gurav
Village Name	Ambavali BK	Ambavali BK	Ambavali BK	Padle	Padle
Area of field, Acre	3	2	5	6	1
Shape of field	Plain Square	Irregular undulating	Plain Rectangular	Irregular Undulating	Plane Square
Irrigation facilities	Yes	No	Yes	No	Yes
Variety	Alphonso	Alphonso	Alphonso	Alphonso	Alphonso
Age of tree, Year	80	25	30	50	15
Row to row spacing, m	16 × 16	12 × 12	10 × 10	10 × 10	10 × 10
Plant to plant spacing	16 × 16	12 × 12	10 × 10	10 × 10	10 × 10
No of tree	120	70	200	250	45
Harvesting practices	Manually	Manually	Manually	Manually	Manually
Yield, kg/tree	90 - 120	60 - 80	60 - 90	60-75	55 - 70
II. Methods adopted by farmer for weeding					
Manual methods	-	Sickling	-	-	Sickling/ Pulling
Mechanical methods	Brush cutter	Brush cutter	Brush Cutter	Brush Cutter	-
Any other	-	-	Herbicides	-	
III. Methods adopted by farmers for fertilizer application					
Time of fertilizer application	June	First fortnight of June	First fortnight of June	June - July	June
Time of spraying	November - April	November - April	November - April	October - May	November - April
Types of organic manure for application	FYM	-	FYM / Vermicompost	Godrej Organic manure	-

Sr. No.	1	2	3	4	5
Types of chemical fertilizer	DAP and MOP	15:15:15	15:15:15 OR 19:19:19	DAP and Urea	15:15:15
Quantity of organic manure, kg/tree	20	-	15	5 -10	-
Quantity of chemical fertilizer, kg/tree	4	7	7	5 - 8	5
Labour required for fertilizer application	4	4	4 - 5	5 -6	2
Time required for fertilizer application, days	3	3	2 - 3	3 - 5	2
Labour required for spraying	2	2	2	4	2
Time required for spraying, days	1	1	1 – 1.5	2	1
Cost of fertilizer application, Rs	2500 - 3000	4000	4000 - 5000	7500-10000	1000 - 1500
Cost of spraying, Rs	500 - 700	500	500 - 800	1000 - 1500	500
Any other	-	-	Thinning and Prunning pracices	-	Thinning
IV. Methods adopted by farmer for digging ring basin					
Manual	Manual	Manual	Manual	Manual	Manual
Any other methods	-	-	-	Placement	

Continued…

Table B - 1 Cultural practices adopted by Mango growing farmers for weeding, fertilizer application and ring making

Sr. No.	6	7	8	9	10
I. Description of field					
Farmer Name	Vijay Limaye	Abdul Mukadam	Mehboob Mukadam	Madhav Paranjape	Mansoor Parakar
Village Name	Padle	Mandivali	Mandivali	Kelashi	Kelashi
Area of field, Acre	8	5	4	3	5
Shape of field	Irregular Undulatin g	Undulating square, Rectangular	Plain	Undulating	Plain
Irrigation facilities	Yes	No	Yes	No	Yes
Variety	Alphonso	Alphonso	Alphonso	Alphonso	Alphonso
Age of tree, Year	40	15	25	30	35
Row to row spacing, m	16 × 16	10 × 10	10 × 10	10 × 10	10 × 10
Plant to plant spacing	16 × 16	10 × 10	10 × 10	10 × 10	10 × 10
No of tree	200	180	100	90	160
Harvesting practice	Manually	Manually	Manually	Manually	Manually
Yield, kg/tree	80 - 100	60 - 80	50 - 90	60-85	65 - 100
II. Methods adopted by farmer for weeding					
Manual methods	-	Sickling	-	-	-
Mechanica l methods	Brush cutter	Brush cutter	Brush Cutter	Brush Cutter	Brush cutter
Any other	-	-	Herbicides	-	Tillage tool
III. Methods adopted by farmer for fertilizer application					
Time of fertilizer application	June	June	June -July	June	June/ September
Time of spraying	November - March	December - April	November - April	October - May	November - April
Types of organic manure for application	FYM	-	FYM / Vermicompo st	Vermicomp ost	Goat litter/ Vermicompo st
Types of	15:15:15/	DAP or	15:15:15	DAP and	15:15:15/

Sr. No.	6	7	8	9	10
chemical fertilizer	19:19:19	Urea		MOP	DAP
Quantity of organic manure, kg/tree	10 - 20	-	10 - 15	5 - 10	5 - 15
Quantity of chemical fertilizer, kg/tree	7 - 8	5 - 6	4 - 5	5 - 6	5 - 7
Labour required for fertilizer application	5	4	2-3	2	2-3
Time required for fertilizer application, days	3	3	2 - 3	3 - 5	2
Labour required for spraying	2	2	2	2	2
Time required for spraying, days	3	2	1 - 1.5	1	2
Cost of fertilizer application, Rs	5000 - 7500	4000 - 5000	4000	2000 - 3000	2000- 5000
Cost of spraying, Rs	1000 - 1500	700 - 1000	500 - 800	500	500 - 1000
Any other	-	-	Thinning	Thinning/ Prunning	Thinning
IV. Methods adopted by farmer for digging ring basin					
Manual	Manual	Manual	Manual	Manually	Manually
Any other	Placements	-	-	-	-

Table B - 2 Plant characteristics of Mango orchard during field survey

Sr.No.	Total Height, m	Height of girth, M	Canopy diameter, m	Ring Diameter, m (50 % Canopy Diameter)	Periphery, m (π× Ring Diameter)
1.	5.01	1.43	6.40	3.20	10.05
2.	4.53	1.07	7.30	3.65	11.47
3.	4.92	1.02	6.75	3.375	10.60
4.	7.35	0.97	7.50	3.75	11.78
5.	5.03	1.00	6.90	3.45	10.84
6.	4.16	1.05	6.29	3.145	9.88
7.	5.20	1.34	8.50	4.25	13.35
8.	5.40	1.30	7.70	3.85	12.09
9.	5.62	1.20	7.29	3.645	11.45
10.	6.74	1.50	8.42	4.21	13.23
11.	5.45	0.95	8.70	4.35	13.67
12.	5.70	1.28	6.56	3.28	10.30
13.	5.30	1.24	7.05	3.525	11.07
14.	6.98	1.40	8.50	4.25	13.35
15.	4.97	1.27	7.65	3.825	12.02
16.	5.00	0.89	9.02	4.51	14.17
17.	6.20	1.90	8.30	4.15	13.04
18.	5.60	1.97	8.20	4.1	12.88
19.	4.05	1.65	9.08	4.54	14.26
20.	6.78	1.23	7.01	3.505	11.01
21.	6.45	0.90	9.17	4.585	14.40
22.	5.30	1.45	7.30	3.65	11.47
23.	4.60	1.56	9.20	4.6	14.45
24.	4.13	1.24	5.90	2.95	9.27
25.	5.60	1.20	7.65	3.825	12.02
26.	4.70	0.96	6.30	3.15	9.89
27.	5.47	1.67	5.70	2.85	8.95
28.	5.60	0.98	7.70	3.85	12.09
29.	4.70	1.08	7.65	3.825	12.02
30.	5.40	1.30	6.40	3.2	10.05
Average	**5.40**	**1.27**	**7.53**	**3.765**	**11.83 = 12**

APPENDIX-C

Physical properties of Vermicompost

Table C-1 Moisture content of Vermicompost (R_1)

Sr. No.	W_1, g	W_2 g	W_3, g	Moisture content wb (%)
1.	43.5	143.5	107	36.50
2.	37.5	137.5	99	38.50
3.	40.5	140.5	106.5	34.10
			Average	**36.38**

Table C-2 Moisture content of Vermicompost (R_2)

Sr. No.	W_1, g	W_2, g	W_3, g	Moisture content wb, %
1.	43.5	93.5	72.01	43.00
2.	37.5	87.5	67.40	40.20
3.	40.5	90.5	68.70	43.40
			Average	**42.20**

Table C-3 Moisture content of Vermicompost (R_3)

Sr. No.	W_1, g	W_2, g	W_3, g	Moisture content wb, %
1.	43.5	143.5	94.5	48.50
2.	37.5	137.5	90.4	46.60
3.	40.5	130.5	84.5	46.00
			Average	**47.05**

Table C-4: Bulk density of Vermicompost at different moisture content

Sr. No.	Moisture Content, %	Weight of sample, kg	Volume of container, m^3	Bulk Density, kg/m^3
1.	36.38	1.140	0.001445	788.93
2.	42.20	1.155	0.001445	799.30
3.	47.05	1.159	0.001445	802.07
			Average	**796.77**

Table C-5: Angle of repose of Vermicompost

Sr. No.	H, cm	R, cm	$\tan\theta$ = H/R	$\theta = \tan^{-1}\left(\frac{H}{R}\right)$, degree	Average
1.	8.82	14.4	0.6125	31.48	31.50°
2.	9.00	14	0.6428	32.73	
3.	8.36	14.3	0.5846	30.31	

APPENDIX-D

Soil Parameters

Table D-1: Moisture content of field soil (R_1)

Sr. No.	W_1, g	W_2, g	W_3, g	Moisture content Wb, %
1.	45.5	153	131.5	21.46
2.	50.5	150	130	20.10
3.	50	140	123.7	18.17
			Average	**19.91**

Table D-2: Moisture content of field soil (R_2)

Sr. No.	W_1, g	W_2, g	W_3, g	Moisture content Wb, %
1.	45.5	148	123	24.39
2.	50.5	150	126.5	23.61
3.	50	145	122.3	23.97
			Average	**23.99**

Table D-3: Bulk density of soil

Sr. No.	Moisture Content (%)	Weight of sample, kg	Volume of container, m^3	Bulk Density, kg/m^3
1.	19.91 - 23.99	2.224	0.001445	1539.10
2.		2.331	0.001445	1613.15
3.		2.256	0.001445	1561.25
			Average	**1571.17**

Appendix E

Calculations of fertilizer dose of complex fertilizer

The recommended dose of fertilizer for mango orchards are 50 kg FYM or 25 kg vermicompost and 1.5 kg N, 0.5 kg P_2O_5 and 0.5 kg K_2O. Complex fertilizer 15:15:15, 16:16:16 and 17:17:17 were used for study.

We calculate the fertilizer dose of above complex fertilizer. Complex fertilizer 15:15:15 means which contain 15 % N, 15 % P and 15 % K means 100 kg of 15:15:15 fertilizer supplies 15 kg N, 15 Kg P, 15 kg K.

So for 1 kg of each number it requires $\frac{100}{15}$ = 6.66 kg. The recommended doses are 1.5 kg N, 0.5 kg P and 0.5 kg K. so for calculate minimum requirements of N: P: K i.e. 0.5 kg.

Therefore, 6.66 × 0.5 = 3.3 kg means 3.33 kg of complex fertilizer (15:15:15) supplies 0.5 kg N, 0.5 kg P and 0.5 kg K, which fulfill the requirements of phosphorous and potassium and some quantity of Nitrogen.

Now, we required 1 kg N which can be supplied through straight fertilizer like Urea.

1 kg × 2.17 = 2.17 k Urea

Therefore, for 1.5 kg N, 0.5 Kg P, 0.5 kg K required quantity of complex fertilizer is (15:15:15) is 3.33.kg and 2.17 kg urea.

Similarly for 16:16:16 is 3.125 kg Complex fertilizer and 2.17 kg urea and 17:17:17 is 2.94 kg complex fertilizer and 2.17 kg urea.

Appendix F

Table F-1 Laboratory calibration of developed fertilizer application system for Vermicompost (Average of three replications).

Sr. No.	Moisture content of Vermicompost, %	Forward speed, km/h	Vermicompost delivery rate at opening position, kg/tree		
			1/2	3/4	full
1.	36.38	1	13.882	23.895	35.073
2.		1.5	9.590	16.867	24.520
3.		2	6.447	11.509	17.854
1.	42.20	1	14.533	25.547	36.878
2.		1.5	9.224	17.038	25.257
3.		2	6.918	12.776	19.944
1.	47.05	1	14.996	27.699	40.060
2.		1.5	10.999	18.470	27.380
3.		2	7.834	14.850	20.536

Table F-2 Effect of hopper filling on fertilizer application rate

Sr. No.	Hopper Level	Replication (g/rev)					Average (g/rev)
1.	**Full Hopper**	502.90	518.72	486.24	478.62	510.33	**499.37**
2.	**3/4 Hopper**	499.18	503.43	484.65	491.75	475.78	**490.58**
3.	**1/2 Hopper**	495.05	490.38	471.57	483.00	478.45	**483.69**
4.	**1/4 Hopper**	485.10	472.34	479.24	479.56	477.76	**478.08**

Appendix G

Field Evaluation

Table G-1 Plant characteristics of field trials at 19.91 % soil moisture content

Sr.No.	Total Height, m	Height of girth, M	Canopy diameter, m	Ring Diameter, m (50 % Canopy Diameter)	Periphery, m (π× Ring Diameter)
1.	5.50	1.10	8.25	4.12	12.94
2.	4.20	1.00	5.30	2.65	8.32
3.	4.57	0.85	6.62	3.31	10.40
4.	4.26	1.00	6.50	3.25	10.21
5.	6.08	1.64	9.35	4.67	14.67
6.	5.52	1.36	8.00	4.00	12.57
7.	5.95	1.30	6.70	3.35	10.52
8.	4.85	0.90	5.20	2.60	8.17
9.	7.40	1.23	9.20	4.60	14.45
10.	6.50	1.42	9.37	4.68	14.70
11.	7.25	1.70	9.30	4.65	14.61
12.	6.38	1.40	8.20	4.10	12.88
13.	6.10	1.30	7.70	3.85	12.09
14.	3.54	0.70	5.40	2.70	8.48
15.	5.76	1.15	7.25	3.62	11.37
16.	6.40	1.20	11.00	5.50	17.28
17.	6.20	1.05	10.05	5.025	15.79

Table G-2 Plant characteristics of field trials at 23.99 % soil moisture content

Sr.No.	Total Height, m	Height of girth, m	Canopy diameter, m	Ring Diameter, m (50% Canopy Diameter)	Periphery, m (π× Ring Diameter)
1.	5.95	1.30	9.70	4.85	15.24
2.	6.20	1.05	10.50	5.25	16.49
3.	5.50	1.12	8.15	4.07	12.80
4.	3.56	1.25	7.15	3.57	11.23
5.	4.26	1.13	8.90	4.45	13.98
6.	7.50	1.70	9.40	4.7	14.77
7.	6.08	1.64	9.35	4.67	14.69
8.	4.2	0.95	7.15	3.57	11.50
9.	6.40	1.50	11.00	5.5	17.28
10.	6.72	1.45	10.45	5.22	16.42
11.	4.70	0.90	9.70	4.85	15.50
12.	4.79	1.17	8.70	4.35	13.67
13.	5.76	1.15	10.25	5.12	16.10
14.	6.10	1.30	7.70	3.85	12.09
15.	4.00	0.60	10.00	5.00	15.71
16.	4.60	1.15	7.46	3.73	11.72
17.	5.80	1.25	8.30	4.15	13.04

Appendix H

I. Cost estimation of developed power weeder operated fertilizer application system for mango orchards

Table G-1 Cost of material required for fabrication

Sr. No	Particular	Materials and specifications	Weight, kg	Rate, Rs/kg	Amount Rs
1.	Wheel	MS flat 31×5 mm	2.64	60	365
2.	Vermicompost and fertilizer hopper	12 SWG MS sheet (3 mm)	20.7	65	1345
3.	Main shaft	MS Rod	3	60	180
4.	Agitator shaft and feed shaft	MS Rod	4	60	240
5.	Frame	MS square pipe 37.5 ×3 mm	25	55	1375
6.	Chain and sprocket	4 sprocket with 14 teeth 60 mm dia., chain pitch 12.5 mm,	-	110	440
7.	Chain	12.5 mm pitch	-	150	250
7.	Fertilizer delivery tube	Polythene	-	50	50
8.	Fertilizer metering mechanism	Plastics rotor	-	100	600
9.	Ridger	Medium carbon steel and 14 SWG MS sheet	5	65	325
10.	Furrow opener	MS flat bar 50 ×12	3.5	62	217
11.	Soil covering device	MS square pipe 37.5 ×3 mm	5	55	275
12.	Clutch	MS round bar 25×3 mm	1	65	65
13	Fabrication cost				3000
Total materials cost, Rs					**8727**

II. Cost of operation of power weeder

A. Fixed cost

1. Depreciation/ h **=** $\frac{C-S}{L\times H}$

$= \frac{70000-7000}{8\times1000}$

= Rs.7.9 /h

2. Interest/ h @ 10 % = $\frac{C+S}{2}\times\frac{i}{100\times H}$

$= \frac{70000+7000}{2}\times\frac{10}{100\times1000}$

= Rs. 38.5

3. Housing cost, Insurance cost, Taxes @ 1 % of the initial cost

Housing cost/ h = $\frac{70000\times1}{100\times1000}$

= Rs. 7

Total fixed cost = 7.9 + 38.5 + 7

= Rs. 53.4

B. Operating cost

1. Fuel cost/hr = 1.200 X 90

= Rs. 108

2. Cost of lubricant/h = Assume 25 % of fuel cost

= 0.25 X 108

= Rs. 27

3. Repair and maintenance cost @ 6 % = $\frac{70000\times5}{100\times1000}$

= Rs 35

4. Wages of operator/ h @ 200/ day = 200/8

= Rs 25/ h

Total operating cost = 195

Total cost of power weeder per hour = Fixed cost + Operating cost

= 53.4 + 195

= Rs. 248.4/h

III. Cost of operation of developed power weeder operated fertilizer application system for mango orchards

A. Fixed cost

1. Depreciation/ h = $\frac{C-S}{L \times H}$

$= \frac{8727-872.2}{8 \times 300}$

= Rs. 3.27 /h

2. Interest/ h @ 10% = $\frac{C+S}{2} \times \frac{i}{100 \times H}$

$= \frac{8727+872.2}{2} \times \frac{10}{100 \times 300}$

= Rs. 1.59

3. Housing cost, Insurance cost, Taxes @ 3.5 % of the initial cost

Housing cost/ h = $\frac{8727 \times 3.5}{100 \times 300}$

= Rs 1.02

Total fixed cost = 3.27 + 1.59 + 1.02

= Rs. 5.88

B. Operating cost

1. Repair and maintenance cost @ 5 % = $\frac{8727 \times 5}{100 \times 300}$

= Rs. 1.45

2. Total cost of operation of developed fertilizer application system per hour = Fixed cost + Operating cost

= 248.40 + 7.73

= 255.73/h

Total cost of operation of fertilizer application system per ha = 255.73 x 05

= Rs. 1278.65 /ha

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In

FARM MACHINERY AND POWER

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