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MECHANIZATION IN FODDER CROP PRODUCTION–A REVIEW

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SUMMARY

Livestock sector plays an important role in the Indian economy and is a source of subsidiary income for many resource poor families. Livestock rearing of society at rural or urban landscape ensures healthy and nutritious diets and at national and regional levels, it supplies affordable, nutritious and safe animal sourced food to the people. Most of the fodder requirement is met by feeding crop residues and grazing land. Major fodder crops grown in India are sorghum, cowpea, napier-bajra hybrid, pearl millet, maize, oats, berseem, lucerne and rye grass, etc. India's fodder crop and livestock sectors are interrelated to each other. For economical and sustainable cattle farming, fodder production round the year is highly essential. Feeding of green fodder to dairy animals play an important role in sustainability of dairy farming. However, in present situation the supply of feed to livestock is not able to meet the demand, and it is urgent to increase the availability of feed resources. In Indian conditions, major farming community falls under small (1-3 ha field size) land holding. A small farmer, usually possessing 2-10 numbers of animals allocates small portion (up to 10 per cent) of his cultivated land to fodder cultivation. Accordingly machinery and their size are required in Indian condition to fulfill their needs. Optimum production and utilization of forage crops is labour-intensive, which ultimately increases the cost of cultivation. This demands appropriate mechanization in fodder production and utilization. Machines in cultivation and utilization of fodder includes sowing machines, weeding machines, harvesting machines, chaff cutting machines and post harvest processing machines. Farm mechanization in India is about 40-45 percent which is very low when compared to countries like US, Brazil and China according to International Exhibition and Conference on Agri-Machinery and Equipment, 2015. Mechanization encourages the improvement of efficiency of large scale production and ultimately leads to urbanization and commercialization in agricultural sector.

Key words : Mechanization, seed separator, fodder harvester, bailer, thresher with urea treatment, feed block making machine, feed pelleting machine, hydroponics

Livestock production is the backbone of Indian agriculture which contributes 4.11 per cent of national GDP and 24.60 per cent of agricultural GDP (GOI, 2017). The livestock sector contributes to the livelihoods of one billion of the poorest population in the world and employs close to 1.10 billion people. Forage based system contains a substantial component of animal production. In the diverse climate of India different forage crops are used but area under cultivated fodder is stagnating to around 8.5 million ha, mainly on account of pressure of human population for food and other cash crops. Productivity of animals is 20-60 per cent lower than the global average due to improper nutrition, inadequate health-care and management. India with only 2.29% of land area of the world, is maintaining nearly 17.4% of world human population and 10.7% of livestock (more than 510 million heads) creating a huge pressure on land, water and other resources (Roy *et al*., 2019). There is tremendous pressure of livestock on available total feed and fodder, as land available for fodder production has been decreasing. At present, the country is facing a net deficit of 35.60% green fodder, 10.95% dry crop residues and 44.00% concentrate feed ingredients (Anonymous, 2013). Deficiency of feed and fodder accounts for half of the total loss, followed by the problems of breeding and reproduction (21.1 per cent), diseases (17.9 per cent) and management (10.5 per cent) (Sahay *et al*., 2016). It is an urgent need to meet the demand of increasing number of livestock and also enhance their productivity for which availability of feed resources have to be increased.

Need for mechanization in fodder crop production

Cultivation and utilization of fodder involve operations similar to any other crop growing practice like preparation of seedbed, sowing of crop, weeding,

harvesting etc. It becomes important to perform initial processing of harvested fodder crop before feeding to animals. Fodder production, its processing and utilization requires intense labour involvement, more time and high energy. Optimum production and utilization of forage crops demand minimum, critical as well as timely operation. Delay in fodder production operation often causes loss of moisture content and deterioration of fodder quality rapidly (Sahay *et al*., 2016). Mechanization facilitates inter-culture activities and sowing operation too which intern produces a good quality fodder. Moreover, nutritious fodder is required to enhance the quality of milk. Mechanization is an essential step to maintain the health of cattle and its produce (Moharpatra, 2016).

Mechanization gaps

Cattle farms based on grassland are dynamic system and it is difficult to manage, mainly because of their sensitivity to uncontrollable environmental factors. Dheeraj and Manoranjan (2017) found that 0.87 hp ha^{-1} utilization of farm power in terms of available machinery for farm operations which was established less than reported a value of power utilization of 1.5 hp ha^{-1} for successful farm operation through mechanization. To meet the growing demand of population and productivity of land, agriculture mechanization is one of the important promising approaches (Barman *et al*., 2019).

Machines in fodder crop production

Sowing machines

1. Seed drill

Cultivated fodder is usually sown by the method of broadcasting where the removal of weed becomes time and labour consuming. In such cases, weeding is often limited to roughing due to which weeding efficiency is reduced. Weed removal is mandatory when the crop is taken for certified seed production. Weeding can be made easier and cheaper when crop is sown in line using a seed drill. Sahay *et al* (2016) reported that the seed yield increases to 4.2 q ha^{-1} in the berseem crop sown using seed cum fertilizer drill as against 1.8 q ha^{-1} in the berseem crop sown by broadcasting due to better weed management in the line sown crop. ICAR-IGFRI, Jhansi (U.P.) in collaboration with ICAR-CIPHET, Ludhiana (Punjab) developed berseem-chicory seed separator for separating chicory seeds from berseem seeds before sowing (Tyagi *et al*., 2018).

2. Seed cum fertilizer drill

In fodder production, often the requirement is to grow the crop in mixed cropping pattern in large field. A seed cum fertilizer drill enables sowing in mixed cropping pattern. When this machine was used to sow fodder crops cowpea and sorghum in mixed cropping system to form paired rows of cowpea and sorghum in the field, the yield was higher for both green fodder (GFY: 36.9 t/ha) and dry matter (DMY: 5.04 t/ha) compared to conventional method (GFY: 25.4 and DMY: 3.5 t/ha) of sowing. The other major advantage of this machine is coverage of more area in the same time compared to other methods of sowing (Sahay *et al*., 2016).

3. Raised bed planter

Fodder crop production requires intensive application of irrigation in the field. Water conservation in irrigation intensive cropping is cost and labour saving and also natural resource optimizing. Performance of a raised bed planter was studied by (Sahay *et al*., 2016) in respect of saving of water resources in fodder oats and fodder sorghum and reported that water conservation in raised bed and furrow system of plantation with 50 per cent deficit irrigation produces 9 per cent less green fodder yield, but saves 50 per cent irrigation with a greater water productivity of 6.82 kg m^{-3} compared to no deficit irrigation. In Oats (JHO 822) green fodder yield increased by 10.5 per cent apart from saving in irrigation of 50 per cent. Raised bed and furrow system with IW/CPE of 0.5 is recommended for oats (JHO 822).

Weed control machines

Not all weedy plants are detrimental to pastures. In fact, some weedy plants provide nutritional value to grazing animals thus, judicious management decisions are often required to determine when or if weed control should be initiated in a pasture (Baker, 1974). Some weedy plants are unpalatable compared with the desirable forage species, thus they are not normally consumed by animals (Green and Martin, 1998). Weeds compete with the main crop for inputs and reduce the crop productivity. Sometimes weed infestation is so severe that main crop get suppressed

and the losses are accounted as high as 75 to 90 per cent (Mertens and Jansen, 2002).

1. Boom sprayer

Knap-sack sprayers cover lesser area and consume more man power to cover unit area of the field. Use of pre-emergent weedicide is more effective and allows the crop to germinate with higher vigour. High capacity sprayers cover more area in unit time (Mohamed *et al*., 1997). In fodder crops pre-emergence spray of weedicide is more appropriate as weeding is usually ignored after sowing. Boom sprayer forms very small size of droplets due to high velocity air flow from the blower having advantage of spraying low volume of weedicide into a large coverage area. Uniform coverage of large area results in reduction of losses of expensive and environment sensitive chemicals (Sahay *et al*., 2016).

2. Power weeder

Mechanical weeding is one of the effective methods to control weeds. It has added advantage of loosening the soil, conservation of moisture by aeration of soil (Cordill and Grift, 2011). Mechanical weeding can be done either manually or by power weeder. Power weeder is an engine operated machine having higher field capacity and lower cost of operation compared to manual weeding and performs operation in lesser time. Sahay *et al* (2016) conducted an experiment in ICAR-IGFRI, Jhansi to evaluate the performance of power weeder in guinea grass. Considering the field capacity of 0.15 ha/h, the cost of weeding for one hectare was found to be Rs. 1375 whereas when manually done with a spade the minimum cost was Rs. 4000/ha. The use of power weeder is advantageous, especially in wide spaced row fodder crops.

Harvesting machines

Harvesting of green fodder requires more energy due to its multi-cut nature of harvesting. There are different machines available for harvesting green fodder that can be chosen based on the requirement, type of crop, size of field and nature of crop.

1. Vertical conveyor reaper

Reapers are used for harvesting of crops mostly at ground level and are classified on the basis of conveying of crops. It avoids fuel consumption, labour requirement (Chavan *et al*., 2015). Vertical conveyor reaper has proven to be a good harvesting machine for harvesting of fodder crops that resembles wheat in harvesting parameters. Planning and implementing an efficient machinery system requires the availability of approximate data on the effective field capacity of the machinery used in farming operations (Amiama *et al*., 2010). The precautions for use of self-propelled reaper include operation in level field free from stones and in sparsely spaced bunds. Field capacity of vertical conveyor reaper was 0.25 ha/h. The cost of harvesting using vertical conveyor reaper was Rs. 1830 compared to Rs. 4000/ha with manual labour giving direct saving of Rs. 2170/ha along with saving time (Sahay *et al*., 2016). A design of self propelled vertical conveyer reaper was introduced by IRRI for harvesting of cereal crops. However, its performance in tall crops was found unsatisfactory. Incorporation of an adjustable third conveying belt in the vertical conveyer reaper machine to improve conveying effectiveness in case of tall fodder crops was found successful (Singh *et al.*, 2008).

2. Engine operated riding type reaper binder

Engine operated riding type reaper binder harvests the crop in field, binds it in bundle, the bundles are collected later and fed in to the thresher directly. This machine is more useful as it performs one more set of operation compared to vertical conveyor reaper that is making bundles. This saves labour in collection of harvested crop and making bundles (Sahay *et al*., 2017). The machine has two pneumatic wheels and one support wheel. Above support wheel, there is operator seat where an operator sits and controls the machine. The cost for harvesting and binding with the machine was Rs. 1580 per hectare compared to Rs. 4000 per hectare with manual labour with a saving of Rs. 2420 ha^{-1} in cost of operation along with saving in scarce labour (Sahay *et al*., 2016).

3. Engine operated riding type fodder harvester

Engine operated riding type fodder harvester is provided as an attachment to reaper-binder machine which is a useful machine for soft forage crop like berseem and lucerne. The machine constitutes a cutter bar for harvesting green fodder and windrower for making rows of harvested fodder. Cutter bar mechanism allows covering more area in harvesting of fodder. Near the bunds some running length of field

up to 1.0 m is left uncut. So, when using this machine, field should be well leveled and bunds should be made at longer distances. Also it is advisable to operate the machine after 5-6 days of irrigation in the field.

4. Tractor operated cutter bar harvester

Tractor operated cutter bar type fodder harvester consists of a reciprocating cutter bar operated by tractor PTO and the machine is mounted on a frame attached by 3 point hydraulic linkage of tractor. The field efficiency of a tractor operated cutter bar harvester was in the range of 60-72 per cent and the actual field capacity was in the range of 0.25 to 0.3 ha/h in berseem, a soft stemmed fodder crop. It gave harvesting efficiency of 98 per cent (Sahay *et al.*, 2016). The machine is able to accommodate well on the bunds of height up to 25 cm.

5. Engine operated grass cutter

There are different heavy machineries to harvest fodder in cultivated lands. But often availability of fodder is there in range lands where the use of heavy machine or tractor becomes difficult. So, machines which can recover the fodder from such land are necessary. A hand held grass cutter can be to harvest fodder from such undulated lands. A hand held range forage harvester serves purpose of harvesting well on the unapproachable range lands. Field capacity of machine is in the range of 0.14 to 0.16 ha/h as against 0.004 ha/h with the manual sickle in undulated terrains. The cost of operation with this machine was Rs. 1200/ ha compared to Rs. 4000/ha for manual harvesting and there was saving of time resulting in to more recovery of fodder from range lands (Sahay *et al.*, 2016).

6. Tractor operated shear plate fodder harvester-chaffer-loader

Tractor operated shear plate fodder harvester-chaffer-loader is a machine that can harvest, chaff and load fodder in the trolley and also bears relatively lesser cost. The harvesting device of the machine uses two shear plates which are fixed on two rotating drums. Rotating drums directs the crop inside the machine and the shear plates cut it from below. It can harvest the fodder crop up to 10 cm height from the ground level. The advantage of shear plate cutting is that there is no frequent break up of shear blades in the field conditions and cutting of harvested crop takes place effectively. After cutting, the crop is conveyed to chaffing mechanism with two chopping blades and 12 number of blower fins to pass the chaffed material in the blow duct. The chopped material is passed with wind blow and can be guided to any direction with wind for unloading (Sahay *et al.*, 2016).

7. Tractor operated flail fodder harvester-chaffer-loader

Tractor operated flail type fodder harvester-chaffer-loader is also a machine to harvest the fodder crop in the field, chaff the fodder simultaneously and load it in to the trolley following with the wind blow directed for unloading. It consists of a rotary shaft on which flails are mounted to harvest the crop, an auger for conveying the cut crop, a cutter for chopping the cut crop and blowers which conveys the chopped material through the outlet. It is suitable for fodder crops like oats, maize, sorghum and bajra napier hybrid. The machine performs optimum when the crop height is up to 2 m. Beyond 2 m, wrapping of crop and crushing of plants occurs, thus decreasing the harvesting efficiency of the machine (Sahay *et al.*, 2016). This machine is suitable for large scale dairy farms where harvesting of more than 2 ha area is to be done daily. The chaffed material can be used directly for feeding and the excess material may be used for making silage.

(Source:http://ecoursesonline.iasri.res.in/pluginfile.php/2529/mod_page/content/1/Module%204%20Lesson%207%20Fig.7.3.jpg)

Fig. 1. Tractor operated flail fodder harvester-chaffer-loader.

8. Tractor drawn paddy straw reaper

The tractor drawn paddy straw reaper was evaluated at farmers field at Ludas village of Hisar district for optimization of cylinder speed (550, 750 and 950 rpm), forward speed (1.0, 1.5 and 2.0 km/h), crop moisture content (20.8 to 50.2 %) in relation to field capacity, fuel consumption, straw size and straw

recovery in paddy. The field capacity, fuel consumption, straw size and straw recovery at optimum conditions were 0.20 ha/h, 5.66 L/ha, 3.46 cm and 62.89 %, respectively. Moisture content of 20.8 per cent, forward speed of 1.5 km/h and cylinder speed of 950 rpm was found optimum for paddy variety Pusa-44 (Ujala *et al.,* 2020).

Chaff cutting machines

Fodder-cutter machines are used by farmers in India for preparation of fodder for the livestock they own. Using fodder cutters, the cost of operation and cutting time can be decreased up to 70-80 % as compared with manual cutting (Mohan *et al*., 2004).

1. Manually operated chaff cutter

Manually operated chaff cutter consists of feeding trough, cutting blades mounted on a hollow flywheel, cover plate, feed rolls, shear plate, handle and stand. The cutting edges are made sharp. The machine is operated by two persons, one feeds the forage or grass in the feeding trough and another rotates the flywheel with handle. The material fed in the hopper is gripped between the feed rolls which pull it and the material gets chopped between blades and stationary shear plate. The length of chopped material can be varied (16-32 mm). Dry as well as green fodder can easily be chopped with the machine.

(Source: http://ecoursesonline.iasri.res.in/pluginfile.php/2530/mod_page/content/1/Module%204%20Lesson%208%20Fig.8.3.jpg)

Fig. 2. Manually operated chaff cutter.

2. Electric operated chaff cutter

Electric motor operated chaff cutter consists of heavy duty frame mounted on wheels, feeding chute, conveyor chain, chopping mechanism, blowing mechanism and transmission mechanism. For safety of operation, the unit comes with self-feeding device with feed reversal mechanism.

3. Tractor operated movable chaff cutter

Electrically operated chaff cutters are usually installed at one place and all the materials of chaffing is brought at the chaffing yard. This is labour and time consuming. If the chaff cutter is taken to the place where material is heaped, labour and time can be saved; a new generation tractor operated movable type chaff cutters have been developed from ICAR-IGFRI, Jhansi. Tractor operated movable chaff cutter is brought to the place where material for chaffing is heaped and chaffing is done there itself. The machine was operated for chaffing the green fodder crops like sorghum, maize, cowpea, napier-bajra hybrid grass, cenchrus grass, guinea grass and hay fodder of sorghum and cowpea. Tractor operated movable chaff cutter was found efficient for chaffing of fodder crops having stem thickness up to 33 mm in case of Napier grass. Chaffing efficiency of freshly harvested fodder was 100 per cent. Whereas, it was 98.2 per cent in case of dried hay material as the machine left dry leaves of sorghum as uncut in the sizes of 100-150 mm (Sahay *et al*., 2016).

The performance of the chaff cutter cum grinder was tested in fodder crops (maize and sorghum). The output capacity of machine for wet fodder was 272 kg/h for maize, 330 kg/h for sorghum, and for dry fodder 174.9 kg h^{-1} for maize and 202.9 kg/h for sorghum also the performance of the grinder is 95 kg/h for the maize grains and 100 kg/h for the sorghum. Chaffing efficiency of the machine for wet fodder was observed 84.15 per cent for maize, 86.5 per cent for sorghum and for dry fodder it was found 80.5 per cent for maize and 86.3 per cent for sorghum and for the grinder it should be 96 per cent and 95 per cent for the sorghum and maize grain. On these results the overall performance of chaff cutter cum grinder was found satisfactory and it is suitable for small and medium farmers (Nimbalkar, 2017).

Fodder cutting machines are major cause of serious injuries to adults and children in the villages of northern India. Among agricultural machine related injuries fodder cutter machine constitute a significant proportion of all injuries (Kumar *et al.,* 2013). In the adults, injuries occur from feeding side while feeding the fodder to the machine while children get injured while playing with the machine (DeMuri and

Purschwitz, 2000). Mohan *et al* (2004) conducted a community based study in north India showed that all age groups sustain fodder-cutter injuries while operating the machine. With detailed study of injuries and machine characteristics it was possible to design simple but effective engineering interventions like warning roller, blade safety guard, gear cover, flywheel locking pin and finger guard to prevent injuries. These specifications are being incorporated in Bureau of Indian Standards, Manually Operated Fodder- Cutter Specification (BIS 7898) and in a proposed standard on ''Safety Requirements for Power Chaff Cutter''.

Shredding stem fodder (hay, silage and haylage) is the main operation in the preparation of fodder mixtures for cattle. It was found that feeding cattle with chopped hay provides an increase in weight gain of 35%, compared with feeding cattle with not chopped hay. A theoretical basis for the fineness adjustment of shredded stem fodder in open-type machines was developed to verify the reliability of the obtained analytical expressions (Abilzhanuly, 2019).

Hassan (2019) conducted a research to evaluate the performance of a small machine to chop the tubers fodder beet, to determine the optimum machine working conditions and to identify a product suitable for making good silage. The optimum conditions for the operation of modified forage chopper machine are cutter head speed of 23.5 m/s, feed mechanism speed of 1.13 m/min and tubers moisture content of 74.4% under using swinging knives. Sarak *et al.* (2018) replaced the electric motor in chaff cutting machine by spring mechanism, so that it is beneficial to farmer. The objective of this project was to run a machine with zero percentage fossil fuel and also it works by manual effort. It cuts the fodder uniformly, which is ideal for the livestock and it is durable, long lasting and low maintenance requiring machine. The effects of the theoretical length of cut, the width of an open throat of a chopper unit and the whole stalk length on percent mass of particles in different diapasons by length were investigated in cylinder and flywheel type forage harvesters. The forage harvesters of this type provide high-quality forage chopping, when relative mass of particles in the range from 8 to 19 mm by length is in the range from 45 to 75 per cent (Belov, 2019).

Post harvest machineries

1. Drying machines

Drying is an essential step involved in hay production. Conditioners, tedding machines or inverters, as well as hay rakes are used for drying of harvested fodder crop. There are many types of tedders and rakes. Tedding machines or inverters are farming implements used for the spreading and turning over of hay in the field. Inverters expose the underside of the hay to the sun, thus facilitating faster drying. Raking machines gather and turn the partially dry hay into a windrow, allowing it to completely dry.

2. Bailing machines

Bailing machines or balers pick up the crop in the field and compress it into a bale. Baling is a process common to both silage and hay production.

2. 1 Tractor operated movable baler

The operation of tractor operated movable baler is independent of electrical power supply with the advantage of carrying the baler to the place of staking of forage material. Baling with movable baler required four persons for collecting the staked material, feeding into the hopper, tying the bales, keeping the bales and maintaining the operation of tractor as well as the machine. The bales made with this machine had average density of 104.8 kg m^{-3}. This machine saves two-third space and facilitates three times more material transportation in a tractor trolley weighing 9.66 quintals in comparison to loose grasses weighing 3.5 quintals (Sahay *et al*., 2016).

2. 2 Tractor operated field baler

Tractor operated field baler has the capacity to collect the spread grasses or hay material from the field. The bales made with field baler had average density of 108.6 kg m^{-3} with average baling capacity of 85.7 q h^{-1}. Sahay *et al*., 2016 reported that the cost of operation with field baler was Rs.1451.0 h^{-1} with output capacity of 85.7 q h^{-1}. This machine can be used to bale the left out straw in the field to address the problem of pollution created by burning of left out straw in the field.

3. Wrapping machines

Wrapping machines wrap bales of hay or silage. They are variety of shapes and sizes in wrapping machines. However, regardless of the type, the common purpose is to preserve the quality and protect the bales from external factors (Lacey, 2002).

Multi-functional machine (MFM)

For the production process of silage bales a new MFM is designed to execute the operations of raking, baling and wrapping with a unique device integrating three functional modules. The front braces of the machine move close to the soil forming a central windrow. The baler pickup system collects and accumulates the windrow in the baling chamber. Once the bale is complete, the MFM stops for a time to bind the bale with twine or net. As soon as the bale is unloaded to the wrapping area, the baling chamber immediately re-starts to process the following bale while the wrapping system envelops the first bale with a polyethylene film. Once the wrapper unit completes the bale filming, during the next stop, the completed bale is unloaded onto the ground (Bortolini *et al*., 2014).

4. Thresher

Thresher with urea treatment system

Urea treatment of straw improves the quality of straw by breaking the ligno-cellulosic bond and enriching the nitrogen content in the straw. Crude protein content of the treated straw generally increases from 3.5-4.0 to 8-9 per cent (Sahay *et al*., 2016). The advantage of this technology is that value of straw increases, fat per cent increases in animal milk. Quantity of grain feed is reduced and green fodder can be saved.

5. Feed processing machines

5.1 Feed block making machine

Feed block making machine compress the feed mixture to certain pressure that binds the ingredients together to form blocks. A force feed mechanism is provided for the pre compression of the loose herbage in the hopper that increases the hay input inside the compression chamber. A feed block making machine reduces transportation cost and storage space and provide better safety during transportation.

5.2 Compact feed pelleting machine

Compact feed pelleting machine consists of an input hopper to feed the material, an auger, extrusion head on the auger and pressure plate. Feed material consisting of berseem hay, lucerne hay, subabul leaves

(Source:http://www.new-ag.info/en/image/08/01/foc341_1.jpg)
Fig. 3. Feed block making machine.

or other top feeds mixed with dry grass or wheat straw is used for making feed pellets. In order to enrich the feed pellets additives like urea, molasses, concentrate mixture, minerals and vitamins are also added. All ingredients are mixed well to make a homogeneous mixture. Water is then added to bring the moisture level of the mixture up to 55 – 60 percent. This is required to facilitate the free flow of material through the pelleting machine. While passing through auger the feed mixture gets converted into dough and extruded out through the holes on the pressure plate in the form of cylindrical bars. These cylindrical bars break into 10-15 cm long pieces due to their own weight, which are known as feed pellets. These feed pellets are then dried upto 10-15 per cent moisture content. These pellets can be stored for lean period and these are also suitable for transport to long distances (Sahay *et al*., 2016).

(Source: http://www.igfri.res.in/images-new/fmpht-feed-palleting.jpg)
Fig. 4. Compact feed pelleting machine.

5.3 Tyre type seed pelleting machine

Tyre type seed pelleting machine uses a pneumatic tyre, rotated on its axis through a supporting frame. The seed with loose fine soil is filled in the inner side of tyre and water is sprinkled over it gradually while rotating the tyre. Pellet formation takes place after 4-6 minutes at proper moisture content and are taken out and dried in the shade. This machine works effectively at 30 rpm (Sahay *et al*., 2016).

Gageanu *et al*. (2019) conducted an experiment for pelleting green fodder (alfalfa, wheat and rapeseed stalks) aimed to be used as animal feed, with and without using additives (corn starch and sugar beet). The use of additives was found to have a beneficial effect on the main quality attributes of animal feed pellets. Nutritional quality improved from 3965.56 to 3989.08 by adding sugar beet, durability improved from 87.2 to 94.5 % by adding corn starch.

Hydroponics

The word hydroponics is derived from two Greek words hydro means 'water' and ponic means 'working'. Fodder produced by growing plants in water or nutrient rich solution but without using any soil is known as hydroponics fodder or sprouted fodder (Dung *et al*., 2010). Hydroponics is produced in greenhouses under controlled environment within a short period. A greenhouse is a framed or inflated structure covered with a transparent or translucent material in which the crops could be grown under the conditions of at least partially controlled environment. However, the structure should be large enough to permit a person to carry out cultural operations .The greenhouse for the production of hydroponics fodder can be either a hi-tech greenhouse type or a low cost greenhouse type as per the financial status of the farmer and availability of building material (Naik *et al*., 2013).

Solar assisted hydroponic gadget

Solar assisted hydroponic gadget is specially designed for green fodder and small and marginal farmers easily adopt this gadget for the fodder production for their cattle. Solar operated green fodder gadget utilizes solar thus saves energy cost. This gadget produces good quality of green fodder and saves 60% of water usage. Optimum temperature and light is maintained by automatic controller and thus reduces man power (Kamat *et al.*, 2018).

Manufacturers in Fodder Production Machineries

A.G. Agro Industries (Gujarat), Amar Agricultural Implements Works (Punjab), ASS Foundry and Agricultural Works (Punjab), ASPEE (Maharashtra), Beri Udyog Pvt. Ltd. (Haryana), Bharat Industrial Corporation (Punjab), Bhuvana Enterprises (TN), Central Institute of Agricultural Engineering (MP), Dasmesh Mechanical Works (Punjab), Deccan Farm Equipment (Maharashtra), Droli Industries (Punjab) (Sahay *et al*., 2016).

(Source: IFSRS, Karamana, Kerala)
Fig. 5. Low cost hydroponics structure.

CONCLUSION

The recent trend observed in farm mechanization is application of high capacity machines through custom hiring services. Animal operated equipment will decrease because of decline in number of draft animals. However, the application of power operated implements will increase rapidly. Being the leader in cattle and buffalo population, and livestock population increasing at a rate of 1.23 per cent per year, current fodder production in our country is not able to meet the requirement. India's crop and livestock sectors are interrelated to each other. The interactions between these two sectors are so complex that it would be difficult to separate out the contributions from each sector. Interactions between crop and livestock sector has been weakening over time, which has prompted mechanization of most of the agricultural operations. The mechanization process in fodder crop production requires rapid expansion and further research is required as it has been an emerging concern over several years.

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