International Journal of Agriculture Sciences
ISSN: 0975-3710&E-ISSN: 0975-9107, Volume 9, Issue 55, 2017, pp.-4955-4959.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

DESIGN AND DEVELOPMENT OF A MECHANICAL HYDROGEL APPLICATOR WITH SUITABLE METERING MECHANISM

PATIL D.V.[1*], INDRA MANI[2], ADARSH KUMAR[3] AND LANDE S.T.[4]

[1]Department of FMP, CAE&T, Vasantrao Naik Marathwada Krishi Vidyapeeth, Krishinagar, Parbhani, Maharashtra 431402, India
[2,3,4]Division of Agricultural Engineering, ICAR - Indian Agricultural Research Institute, Pusa, New Delhi, Delhi 110012, India
*Corresponding Author: Email-dvpatilvnmkv@gmail.com

Received: December 19, 2017; Revised: December 25, 2017; Accepted: December 26, 2017; Published: December 30, 2017

Abstract- A mechanical hydrogel applicator machine was designed and developed for application of small granules of hydrogel at uniform rate at field level. Hydrogel are the small granules which help to conserve the soil moisture at root zone depth. Laboratory experiment, using Factorial RBD for three metering mechanisms namely star wheel, screw feed and brush feed were conducted to test their performance on sticky belt in terms of uniformity in distribution pattern of hydrogel granules and efficacy in recommended application rate for designing the mechanical hydrogel applicator. These three metering mechanisms were tested for three different hydrogel sizes namely MS 18 (0.85mm), MS 25 (0.60mm) and MS 36 (0.42mm) at three levels; hydrogel mixed with soil, with fertilizer and with sand. The observed average variation rate (in per cent) from recommended application rate for uniform distribution over m^2 area for hydrogel mixed sand were 9%, 5%, 17.5% for Star wheel, Screw feed and Brush feed metering mechanisms, respectively. Experiment revealed that screw metering mechanism with hydrogel mixed sand showed an optimum average application rate of 2857g against 3000g (3kg ha^{-1}) which was actually required. Screw metering mechanism was found better in uniform distribution of hydrogel granules and application rate when; compared visually as well as through image analysis method. Various machine performance parameters like depth of hydrogel granules placement, average speed of the machine, specific fuel consumption, average field capacity and field efficiency while working in field were also calculated.

Keywords- Hydrogel sizes, metering mechanism, application rate, hydrogel applicator.

Citation: Patil D. V., et al., (2017) Design and Development of a Mechanical Hydrogel Applicator with Suitable Metering Mechanism. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 9, Issue 55, pp.-4955-4959.

Academic Editor / Reviewer: Kannan C. S. Warrier

Introduction

The use of fertilizers and solid amendments like hydrogel in agriculture has generated special interest for their suitable application for increasing crop productivity in the areas where water availability is scarce. Hydrogels are hard granules (semi synthetic polymers) which plays an important role in conserving moisture in soil by their swelling mechanism when they come in contact with water. study took place to investigate the effect of its application on water absorption rate and soil moisture holding capacity of loamy sand soil. Soil water holding capacity was carried out with 5 treatments *i.e*., 0, 0.25, 0.75, 1.25 and 1.75 per cent polymer application by weight. The application of polymer to the soil helped in retaining more moisture in the soil, increased water holding capacity of polymer and decreased infiltration rate soil [1]. Hydrogels are able to absorb up to one litre of water per gram of dry material, without releasing it under compression. The soil with the addition of small quantities of the product is able to remain humid for periods more than four times longer with respect to the soil watered without the presence of the hydrogel [6].

The operational characteristics of four different fertilizing metering systems determined the adequate metering system-product operational parameters, using powder lime, powder gypsum, granular 10-30-10 (N-P-K) and granular urea. Operational differences were fabricated and installed among four types of commercial fertilizer metering systems, including wire auger, star-shaped feed wheel, feed screw and ridged traction wheel. The wire auger and star-shaped feed wheel metering systems were adequate for the distribution of powder products and the feed screw for granulated fertilizers. The wire auger metering system was the best for distributing solid products, while the ridged traction wheels metering system presented low unloading rate uniformity. The star-shaped feed wheel and the wire auger were adequate for distributing great amounts of fertilizers and amendments, while the ridged traction wheel did it for small amounts of such products. The feed screw 1 and 2 are suitable metering systems for granulated products but not for powder products.

The hydrogel can be produced both in form of powder or of a bulky material with a well-defined shape and a strong memory of its shape after swelling. The existing methods of hydrogel application like mixing with soil or seed, broadcasting manually are not efficient and which are leading to loss of hydrogel and non-uniformity. Thus, these methods are inaccurate, time consuming and labour intensive. This problem can be overcome by applying granular hydrogel at proper root zone depth with a suitable applicator. The application methods for the product have been standardized keeping in view its low rate of application i.e.3-4kgha^{-1} for field crops and for the diverse agricultural and forestry applications. The precise application of hydrogel at proper depth and desired rate are the challenging task to be faced at the field level. Suitable metering mechanism is an important aspect while designing a hydrogel or any granular applicator.

The commonly recommended metering system on seed drill are internal double run, stationary opening seed metering with agitator and fluted roller type. Similarly, generally recommended metering mechanism for application of fertilizer or soil amendments are feed screw, wire auger, ridged traction wheels, star shaped wheel [2]. It has been reported that feed screw is one of the most suitable metering mechanism for granulated products. Similarly, the star shaped feed wheel and wire auger have been successfully evaluated for distributing great amounts of fertilizer and amendments. A power tiller operated till plant machine for enhanced wheat production was designed and development [3]. Field performance of this machine was reported satisfactory for seeding of wheat after rice in silt loam soil with the average capacity of 0.15 hectare per hour. The power tiller till plant machine gave about 23 per cent higher grain yield as compared to the conventional tractor farming system.

Granule state hydrogel application to soil by mechanical means is one of the most innovative techniques to conserve moisture at root zone depth of the plant. A suitable design of hydrogel applicator is not available, so there is need to design and develop a mechanical hydrogel applicator to be used in conjunction with normal seed cum ferti-drill or aqua ferti seed drill. This paper deals with the determination of different design values and thus to fabricate its different components for developing prototype and finally field evaluation of its performance.

Materials and Methods

Metering mechanism consists of hydrogel feed hopper, power transmission system, plastic transparent tubes and furrow openers. The design of a metering mechanism and feed hopper was based on physical and engineering properties such as size, shape, bulk density, particle density, angle of repose, coefficient of static friction was considered for design of different relevant components [4]. Based on the information obtained from physical and engineering properties of hydrogel and the requirements for the placement of hydrogel in soil along with seed at the time of sowing different components were designed and developed. In Various sizes of hydrogel particles (MS 18, MS25 and MS36) were taken to test their efficacy in uniform distribution and recommended application of hydrogel at field level.

The seed drill component of aqua ferti. Seed drill consisted of seed metering system along with furrow opener, seed tubes and other support components including frame. As the main aim of the study was to determine the design values of a mechanical hydrogel applicator the crux of the design process was to design the suitable metering mechanism. The chain sprocket power transmission system was set up on hydrogel applicator as per the field requirement and also to match the dimensions of the different components of the existing machine. The mechanical hydrogel applicator for the application of small quantity and tiny size hydrogel granules was attached with an aqueous fertilizer metering system which in turn was a part of the existing aqua ferti. Seed drill.

Table-1 *Statistical methodology for selecting a metering device for hydrogel applicator*

Sl. No	System variables	Levels of variable
1	Hydrogel mesh sizes(S)	3(S_1- MS18, S_2- MS25, S_3- MS36)
2	Hydrogel mix (N)	3(N_1-Hydrogel+ fertilizer, N_2-Hydrogel+ soil N_3- Hydrogel+ sand)
3	Metering Mechanisms(MM)	3(MM_1- Star wheel metering mechanism MM_2- Screw feed metering mechanism MM_3-Brush feed metering mechanism)
4	Replications (R)	3
5	No. of observations (NO)	3*3*3*3= 81
6	Experimental Statistical Design	Factorial Randomized Block Design (Factorial RBD)

Hopper Design

The common shapes of hopper used on seed drill and planter are trapezoidal, circular, semi-circular, pyramidal, square and their dimensions vary according to the type of seed or fertilizer to be sown or apply. The important properties required in designing a hopper for hydrogel applicator are shape, size, bulk density, angle of internal friction for granules. The trapezoidal cross-section of hopper was used on the mechanical hydrogel applicator to facilitate free flow of granules to the metering mechanism. For proper distribution of hydrogel granules, the separate nine hoppers were fabricated in Divisional workshop. These nine hoppers, one each for one feed roller were kept in series and were mounted on a MS flat with fastened nut and bolts to withstand the vibration of seed drill while working in a field. The hopper was fabricated using Mild steel (MS) was filled with hydrogel and sand in proportion as per recommended. The same transmission ratio was applied to three metering systems.

The nine hoppers arrangement for hydrogel applicator was finally mounted on the existing aqua ferti seed drill. The arrangement for mounting below the hopper for mechanical hydrogel applicator was almost same as seed drill attached with fluted roller metering mechanism for wheat sowing. The bottom of the box was flat and rounded at the corners. The inclined guiding plates were fitted at the base to help movement of seed towards the inlet opening of the metering device. The location of nine hoppers on applicator was kept 1100 mm above the ground but at a lower height compared to the seed box of aqua ferti seed drill attached in parallel with the hoppers of hydrogel applicator. The appropriate height helped to keep the hydrogel granule delivery tubes straight without bending. All the relevant information was taken into consideration for designing the hopper. The following data was calculated with respect to different variables for the design hopper [5].

1. Average density of Hydrogel granules (ρ) = 556 kg/m^3
2. Density of sand particle (ρ) =1400 kg/m^3
3. The ratio of the sand and hydrogel was 266:1. Based on this ratio the average density was calculated as 1396 kg/m^3
4. Average angle of slope of hydrogel (α) = 42˚
5. Average angle of slope of sand and hydrogel particles (α) = 35-37 º
6. Angle of repose for designing hopper for mixture of hydrogel and sand =39˚

(ii) The volume of box was determined by adding the volume of two sections of the hopper, section A and section B.

$$V_L = V_A + V_B$$

Where V_h is volume of hopper, VA is volume of section A and VB is volume of section B. The box was assumed to be square at top with sides 15 cm.

Design and fabrication of three metering mechanisms in the divisional workshop

The commonly recommended metering system on seed drill are internal double run, stationary opening seed metering with agitator and fluted roller type. But, most recommended metering mechanism for application of fertilizer or soil amendments is feed screw, wire auger, ridged traction wheels, star shaped wheel. The power transmission system based on chain sprocket was set up on hydrogel applicator as per the field requirement and also to match the components of the above two systems. The three metering systems were developed and tested in laboratory for desired hydrogel application rate and the distribution pattern of hydrogel granules over seed belt.

In case of star wheel metering mechanism, the Nylon rod having 48mm dia. and 50 mm length was selected as a material for designing the metering system. The nine slots were made over the periphery of roller based on the maximum dimensions of the hydrogel particles. The dimensions of slots were obtained according to shape and size of the hydrogel granules. The inner and outer diameter of the roller which carried the roller shaft was 20mm and 48mm, respectively. A split pin was provided in hole with diameter 4mm to fix the star shaped roller on roller shaft. The casing over the roller was the one which is used in seed drill. The nine rotating slots over roller picked up the mix hydrogel and sand particles and discharged them to hydrogel feed tube though funnel with desired rate. The chain sprocket system was mounted to drive the roller having 62 and 16 teeth on large and small sprocket. The 16 teeth sprocket was mounted on the fluted roller metering shaft of seed drill. The same gear ratio was applied to roller shaft of the hydrogel applicator with speed reduction ratio of 4:1 for application of the small recommended quantity of hydrogel granules.

The screw feed metering mechanism is best suited for metering fertilizer or granulated products. The roller used for metering mechanism was of wood type having the dimensions same as of above mentioned star shaped roller. The nine grooves of 32 mm length over the periphery of roller were made. The helical arrangements of grooves were made for long run of granules over the periphery of roller and the actual groove length was kept 38 mm. Power transmission, inner and outer dia., split pin arrangement was same for all three-metering mechanism. The surface finishing in groove was done for the smooth travel of granules over the periphery of roller. The brush feed metering mechanism consisted of a roller made up of wood having same dimensions as that of the other two rollers. The nine holes of diameter 3mm were punched over the periphery at equal distance. The mounting of the roller was done similar to other two metering mechanisms.

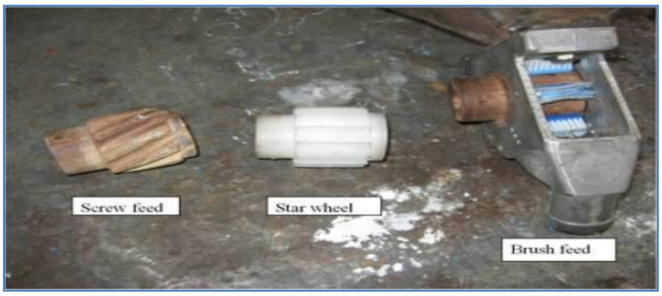

Fig-1 Various metering systems designed and developed in divisional workshop

Table-2 *Design parameters for screw feed metering mechanism*

Sl. No.	Components of hydrogel applicator	Dimensions
1	Nylon rod	48mm x 50mm
2	No. of grooves	9
3	Inner and outer diameter of roller	20mm and 48 mm
4	Split Pin hole diameter	4mm
5	Groove length over roller	3.2mm
6	Actual length of run for granules over roller	3.8 mm
7	No. of teeth on sprocket	64 (large sprocket) and 16 (small sprocket)
8	Power transmission system	Chain and sprocket

Laboratory experiment for evaluating performance of three metering mechanisms

The test was carried out for three metering systems on sticky belt for determining the distribution pattern and application rate of hydrogel granules. The sufficient grease is provided on the belt in order to avoid the bouncing of granules on the belt which was mounted on the experimental set up. The hopper made up of Mild Steel (MS) was filled with sand and hydrogel in 266:1 proportion as per the recommendation. The calibration was done with standard method, such that; after every 10 revolutions of roller, the belt speed and no. of hydrogel particles dropped over per metre length of belt were recorded. The procedure was repeated for all three metering systems with same arrangement of hopper with three different metering units on the sticky belt. The desired rate of granules dropped over belt per square metre area was also recorded for all three mesh sizes (MS 18, MS 25, and MS 36) of hydrogel.

Fig-2 Selection of suitable metering mechanism through sticky belt method

The procedure was replicated for three times with different sizes of hydrogel mixed sand, soil and fertilizer for all three-metering mechanism. The statistical analysis and comparison between all sizes of hydrogel granules mixed with sand, soil, and fertilizer for all three-metering system was obtained using SPSS software. The distribution pattern of hydrogel particles on sticky belt for all the three metering systems was checked and observations were studied for the best performing hydrogel granule metering mechanism.

Tubes for hydrogel application

Transparent PVC pipes having a diameter of 15.4 mm were used to facilitate the flow of hydrogel particles from the seed metering mechanism to the end of the nine furrow openers. Pipes were mounted in such a way that no bends should appear and free flow of hydrogel may be accomplished. These pipes were attached to the furrow opener of aqua ferti seed drill through proper arrangement of separate hole in order to insert hydrogel carrying pipe directly into holes. The precaution was taken such that the hydrogel granule carrying tube should be dry thoroughly. The presence of even very small quantity of water can hamper the application rate of hydrogel applicator. The aqueous fertilizer distribution was also accomplished using a networking of G.I. pipes and PVC pipes [7,8]. To take out flow of aqueous fertilizer from storage tanks, a PVC pipe of 25.4 mm size was provided for connection of two aqueous fertilizer storage tanks.

Furrow opener

The single shovel type furrow opener was developed as per the requirement to open the furrow in the soil and to apply the granular hydrogel with or without required amount of aqueous fertilizer in the furrow alongside of the seed. It was ensured that the depth of operation of furrow opener was more than the seeding depth. This was due to the tendency of loose soil to flow back from the side walls into the furrow as the furrow opener moved forward.

Ground wheel

The ground wheel was provided to drive the metering system. As the speed of the seed metering was controlled by the ground wheel through power transmission system which consisted of chain and sprocket mounted on the shaft of ground wheel and metering mechanism. The specified range of diameter of ground wheel was kept 360 mm as per RNAM test code which has specified 350-450 mm diameter for ground wheel. The dimensions of other machine components particularly frame size and furrow opener height, the ground wheel was taken to match the dimensions of the ground wheel.

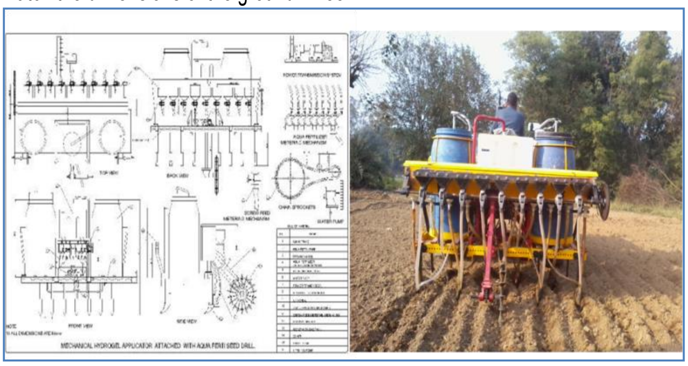

Fig-3 CAD drawing of a hydrogel applicator prototype attached with seed drill

Results and Discussion

Three metering mechanisms namely star wheel, screw feed, brush feed were tested in laboratory on sticky belt by changing velocity ratios using different diameters of pulley. The different diameters of pulley changed the velocity ratios and helped to meet recommended application rate. Hydrogel hopper having capacity 0.5kg was made to with stand on developed metering mechanisms and the velocity ratios was changed to check the uniformity and application rate. The following data was considered for conducting the experiment.

1. Recommended dose of sand for 50m^2 area = 4 kg.
2. Recommended ratio of sand: hydrogel =266:1
3. Width of sticky belt = 20cm
4. Length of sticky belt= 500cm
5. Total sticky belt area = 1m^2
6. Thousand Granules weight for MS 18 = 5.41g
7. Thousand Granules weight for MS 25 = 2.07g
8. Thousand Granules weight for MS 36 = 1.56g

The recommended procedure for calibration was adopted and relevant data was recorded in the laboratory. The weight of mixture displaced from hopper after 10 revolutions was recorded which was taken for further calculation. The number of particles dropped over sticky belt was counted and weight of particles over1m² area was recorded. The furrow width was taken as 20 cm and the granules falling on 5.0 meter length of belt travel was recorded. Thus, the covered area was 1.0 m². Volume of hydrogel and sand mixture displaced from hopper was determined by taking difference of initial quantity of mixture in the hopper and final quantity left over in the hopper. The numbers of particles dropped over sticky belt in 10 revolutions were recorded. The number of granules dropped over an area was calculated based on the following relationship.

S (Number of hydrogel granules) = 1/(a x b)

Where, a: the distance between rows, m

b: granule to granule distance in a row, m

Comparison of three metering mechanisms for uniformity distribution check

The hydrogel was mixed with three levels i.e. hydrogel with fertilizer (N_1), hydrogel with sand (N_2) and hydrogel with soil (N_3) for uniformity distribution check of hydrogel granules on sticky belt. The number of hydrogel granules dropped over per m² area on sticky belt was counted and observed manually and through image analysis for uniformity distribution check of hydrogel granules. Comparison in variation rate was made on the basis of number of hydrogel granules received per square meter area with respective to 1000 granules weights of different hydrogel sizes. It was observed that, optimum numbers of hydrogel granules were received with hydrogel mixed sand compared to other two mixtures; hydrogel mixed fertilizer and hydrogel mixed soil. The factorial RBD experiment was carried out to analysis and understanding the interaction between different variables in applying the recommended rate of hydrogel. The hydrogel-sand mixture was found best among three levels of mixture when calculated based on the performance of uniform scattering of granules over sticky belt.

Table-3 *Variation rate in quantity of hydrogel granules dropped over sticky belt for different metering mechanisms*

Hydrogel Size (MS 18)			
MM	Star Wheel (in %)	Screw Feed (in %)	Brush Feed (in %)
HF	24.7	15.43	23.46
HSD	17.3	11.1	24.7
HS	8.63	3.7	17.3
Average	16.86	10.06	21.83
Hydrogel Size (MS 25)			
MM	Star Wheel (in %)	Screw Feed (in %)	Brush Feed (in %)
HF	15.5	9.73	18.06
HSD	8.56	2.76	21.3
HS	3.47	3.47	13.43
Average	9.16	5.22	17.6
Hydrogel Size (MS 36)			
MM	Star Wheel (in %)	Screw Feed (in %)	Brush Feed (in %)
HF	5.23	4.7	8.5
HSD	2.63	1.93	6.93
HS	4.00	2.93	19.26
Average	3.97	1.23	11.56

Table-4 *Test between Subject effects*

Source	Sum of Squares	df	Mean Square	f -Value	Sig.
Corrected Model	1.398E7[a]	32	437029.78	10.13	.000
Intercept	7.333E8	1	7.333E8	1.700E4	.000
MM	1.034E7	2	5172391.0	119.91	.000
NO	439740.52	2	219870.26	5.10	.010
S	147404.96	2	73702.49	1.71	.192*
R	233712.30	2	116856.15	2.71	.077*
MM * NO	650773.04	4	162693.26	3.77	.010
NO * S	250573.41	4	62643.35	1.45	.231*
S * R	155248.30	4	38812.07	.90	.472*
MM * S	311686.15	4	77921.54	1.81	.143*
MM * R	1294853.48	4	323713.37	7.51	.000
NO * R	156178.52	4	39044.63	.91	.468*
Error	2070501.33	48	43135.44		
Total	7.494E8	81			
Corrected Total	1.606E7	80			

The three mechanisms have their different modus operandi of flow and metering of granules under different treatments. The rate of flow was controlled by their working principle. Three metering mechanisms and three levels of hydrogel mixture influenced the performance of metering system however; the hydrogel size had no significant influence on application of quantity of granules per hectare. The average granules per ha over sticky belt was minimum for star wheel and whereas; it was maximum for brush feed metering mechanism. The average granules obtained per ha for star wheel metering mechanism for hydrogel sizes MS 18 (S_1), MS25 (S_2), MS36 (S_3) were 2481g, 2743g, 2981g whereas for the screw feed metering mechanism the same were 2667g, 2917g and 2942g and the brush feed 3741g, 3639g, 3208g when hydrogel and sand mixture were used. Thus, among three metering mechanism, the screw feed metering mechanism with mixture of hydrogel and sand gave the best performance and was able to apply recommended rate of hydrogel in the field for wheat crop.

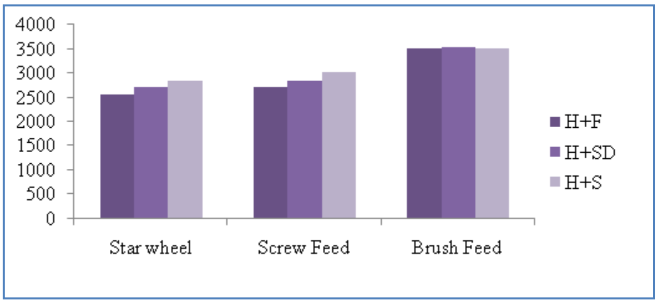

Fig-4 Uniformity distribution check performance for three hydrogel mixtures with different metering systems

Field evaluation of a mechanical hydrogel applicator

The aqua-ferti seed drill existing in the Division of Agricultural Engineering was used in the study. Designed components in workshop were mounted on seed drill for field evaluation of hydrogel applicator prototype. Field experiment for the performance evaluation of tractor operated mechanical hydrogel developed was carried out in experimental field of Division of Agricultural Engineering IARI, New Delhi. The soil of IARI farm has been classified as alluvial soil group and is of sandy loam texture. The theoretical field capacity is the rate of field coverage that would be obtained if the seed drill was operating continuously without interruptions like turning at the ends and filling of hopper. The effective field capacity is the actual average rate of coverage including the time lost in filling hopper and turning at the end of rows.

$$\text{Theoretical field capacity} = \frac{[wxs]}{10}, \text{ ha/h}$$

Where, W: width of coverage, mS: Speed of operation, kmph

Effective field capacity (ha/h) =Area of plot (m²) x 0.36/ Actual time taken (s)

$$\text{Field Efficiency} = \frac{\text{Actual field capacity}}{\text{Theoretical field capacity}}$$

Table-5 *Field performance data of a mechanical hydrogel applicator*

Sl. No.	Performance parameters	Values
1	Average depth of seed placement, cm	5.0
2	Average speed, km-ph	2.8
3	Average fuel consumption, l/h	3.50
4	Average theoretical field capacity, ha/h	0.57
5	Average actual field capacity, ha/h	0.41
6	Average field efficiency, per cent	72.0%
7	Labour requirement, man-h/ha	2.00

The required cost of material for the fabrication of designed prototype was Rs. 33,267/- at the cost of 10% profit.

Conclusion

i) The uniformity and application rate of screw feed metering mechanisms were significantly varied with other mechanisms and found that screw metering mechanism was having better performance for application of hydrogel granules compared to other two metering mechanisms.

ii) The quantity of hydrogel granules received and dropped in and from the grooves of the metering roller were smooth and not disturbed in screw metering mechanism. Whereas, there was bulk feeding in Brush feed metering mechanism.

Application of Research: Uniform Application of small quantity of hydrogel granules with the help of designed hydrogel applicator prototype.

Research Category: Conservation Agriculture

Abbreviations:

MM: Metering Mechanism
HS: Hydrogel+Sand
No.: Number
MS: Mesh Size
RBD: Randomized Block Design

Acknowledgement / Funding: The technical and financial support provided by the Division of Agricultural Engineering, ICAR - Indian Agricultural Research Institute, Pusa, New Delhi, Delhi 110012, India is highly acknowledged. Author are thankful to the Scientific staff of ICAR - Indian Agricultural Research Institute, Pusa, New Delhi, Delhi 110012.

Author Contributions: All author equally contributed

Author statement: All authors read, agree and approved the final manuscript

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors

Conflict of Interest: None declared

References

[1] Vijayalakshmi, Nemichandrappa M., Reddy K. S and Ayyanagowdar M. S. (2012) *Karnataka Journal of Agricultural Science,* 25(4, pp469:471.

[2] Jesesus H., Camacho-Tamayo and Angela M. Barbosa (2009) *Eng. Agric., Jaboticabal,* 29, 4 (605-613).

[3] Varma, M. R. and Tiwari R.C. (2001) Design development and field evaluation of power tiller operated till-plant machine for enhanced wheat production in eastern Uttar Pradesh. XXXVth Annual Convention Indian Society of Agricultural Engineers, Bhuvneshwar, India.

[4] Patil D. V., Indra Mani, Anupama Singh and Cini Varghese (2014) *International Journal of Bio-resource and Stress Management,* 5(2), 234-239

[5] Mohsenin N.N. (1986) Physical properties of plant and animal materials. Gordon and breach Science publishers, Inc. New York.

[6] Alessandro Sannino, Christian Demitri and Marta Madaghiele (2009) *Materials,* 2. Pp. 353-373.

[7] Kant and Mani (2008) Studies on design parameters of aqueous fertilizer placement with seed drill. Ph. D thesis in Indian Agricultural Research Institute.

[8] Camacho-tamayo J. H., Barbosa A. M., Perez N. M., Levia F. R. and Rodriguez G. A. (2009) *Eng. Agríc., Jaboticabal.* 29(4), 605-613.