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Design and Development of Fertilizer Metering System for Tractor drawn Liquid Fertilizer Applicator

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ABSTRACT

A pressurized fertilizer metering system was developed for Tractor drawn Liquid Fertilizer Applicator. The liquid fertilizer metering system constituted a pump, control valve and a distributor unit. A circular distributer with an inner and outer diameter of 52 mm and 72 mm, respectively and a thickness of 10 mm was fabricated. Nine holes, each of 8 mm size were drilled around the periphery of the distributor at a spacing of 10 mm for connecting delivery pipes. A setup was fabricated to measure the discharge pattern and discharge uniformity among delivery pipes. The distribution uniformity was in the range of 96.7 to 99.1 %, 96.7 to 99.5 % and 92.8 to 99.1 %at pressure levels of 0, 1 and 2 kg/cm^2, respectively at different pump speeds. The pumping system used for metering liquid fertilizer was capable of giving a flow rate variation of 0.74 l min^{-1} to 2.85l min^{-1} for different pump rpm

KEYWORDS

Urea Ammonium Nitrate, liquid fertilizer, metering, fertilizer applicator

INTRODUCTION

Major fertilizer sources consumed in India are Urea, NPK complex, Di-Ammonium Phosphate (DAP), Single superphosphate and Muriate of Potash (MOP) (Anonymous, 2016), which are widely used in granular form. Commercially, urea widely used in agriculture as nitrogen-rich fertilizer is mainly produced in a solid form, either as prills, granules or super granules. Prilled Urea is a small aggregate of materials most often a dry sphere of 1 to 4 mm diameter formed from the melted liquid. Prilled urea is popular low cost N fertilizer; there are difficulties in applying it evenly and also in maintaining product quality during handling. The uniformity of particle size is important when using granular urea, both in case of direct application or in blended formulations. The popular methods of application of prilled urea are broadcast and banding (pre-drilled) into the soil. Here, particle size is important to maintain even distribution of urea, particularly during broadcast. Pre-drilling granular urea involves incorporating fertilizer into the soil using sowing equipment. This method of application is better than broadcast as it avoids nitrogen losses due to little opportunity for ammonia gas to escape from the soil. In addition, granular urea is completely water soluble and the most efficient applications occur when the fertilizer get moistened by rain or irrigation water soon after application. A minimum of six to eight millimeters of rain or irrigation water is required for granular urea applications to be effective. High rates of urea create areas of high toxicity around the urea granules as they dissolve which can burn or scorch the emerging seedlings. Insufficient rainfall can lead to losses through volatilization reducing cost effectiveness and crop responses.

There is strong need to avoid use of excessive N as it is unlikely to be effective in increasing crop yields because of its diminishing returns (Tilman *et al.*, 2011). Furthermore, the practice of excessive use of N fertilizer decreases N use efficiency (Peng *et al.*, 2006; Ata-Ul-Karim *et al.*, 2013), causing a series of economic and environmental problems, as only an estimated 30–50% of applied N fertilizer is utilized by crops (Smil, 1999). In addition, nitrogen losses associated with higher application rates can result in leaching (Gheysari *et al.*, 2009) that leads to contamination of surface and subsurface water (Barton and Colmer, 2006) including aquatic ecosystems (Fischer *et al.*, 2010). Therefore, the application of appropriate levels of N fertilizer through improved management is the key to increase N use efficiency (Tilman *et al.*, 2002).

One way to use granular urea is to go for its use in aqueous form. Studies suggested that application of aqueous urea at root zone depth enhanced growth performance parameters in addition to better germination (Kant, 2008). Due to the limitations of prilled urea, liquid fertilizers are popular in foreign countries viz. USA, European Union, Australia and many more.

Liquid fertilizer influences not only initial growth but the overall yield also. However, proper application of liquid fertilizer is a major hindrance. Application of liquid fertilizer alongside the seed needs a precise and proper method to avoid mixing of seed with liquid fertilizer and making mud due to excess application of water at a place. There are various issues which needs to be answered viz. selection and modification of furrow opener for simultaneous placement of fertilizer and seed at differential depth, pressurized metering system and corrosive effect of

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liquid fertilizer on the components of the metering system.

Pressurized liquid fertilizer application system is necessary when it has to be placed in sub-soil. The liquid fertilizer is placed in sub soil through narrow delivery tubes. The opening of fertilizer delivery tubes may be in contact with soil. Hence, the opening of fertilizer delivery tube has high chances of getting clogged due to soil. The pressurised application will reduce the chances of clogging. Keeping this in mind, a pressurized fertilizer metering system was developed for Tractor drawn Liquid Fertilizer Applicator.

MATERIALS AND METHODS

It was important that the liquid fertilizer should get distributed uniformly among different delivery tubes for uniform on field application to avoid over fertilization and under fertilization. The liquid fertilizer metering system was based on design of liquid fertilizer distribution system for uniform application, selection of optimum operating conditions and control system for pressure and flow rate.

Design and fabrication of pressurized liquid fertilizer metering system

A circular distributor made of nylon was designed and developed. It had a simple design with central inlet opening into a disc shaped chamber, Fig. 1. To maintain uniform pressure and uniformity of flow, the volume of the inside chamber of distributor was kept as minimum as possible. A circular distributer with inner and outer diameter of 52 mm and 72 mm, respectively and a thickness of 10 mm was fabricated. Nine holes each of 8 mm size were drilled around the periphery of the distributor at a spacing of 10 mm for connecting delivery pipes. One end of delivery pipes was connected to distributor through connector while the other end delivered the liquid fertilizer at set depth of furrow opener. The connectors provided a pressure sealing for delivery pipes at distributor end (Fig. 2). The discharge from each pipe was measured and used for analysis of flow uniformity.

From the geometry,
Inner perimeter of the chamber, mm = (diameter of connector x no. of connectors) + (Space among two connector x no. of connectors)

= 8 x 9 + 10 x 9
= 162 mm

Inner Diameter of Chamber, mm = Perimeter/π
= 162/ π
= 52

Keeping the thickness as 10 mm,
Outer diameter of the chamber, mm = Inner diameter of chamber + thickness
= 52+2 x 10
= 72

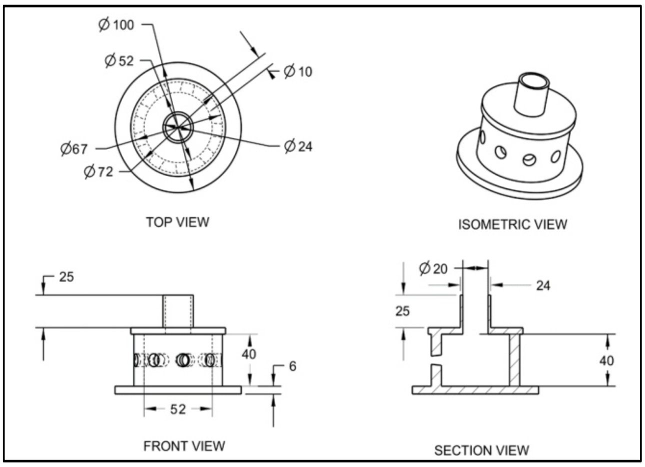

Fig. 1: Different views of the cylindrical fertilizer distributor

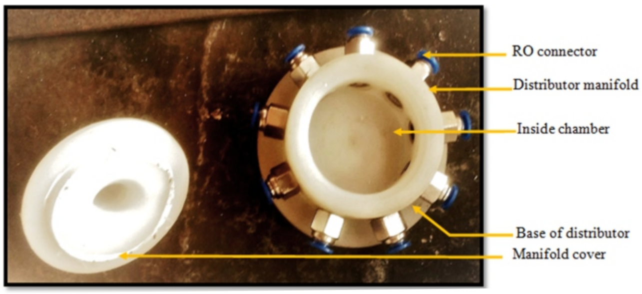

Fig. 2 : Different parts of Liquid fertilizer distributor

Experimental set up for evaluation of liquid fertilizer metering

The developed system was evaluated for performance at varying operational conditions to select optimum operating conditions. The main design variables of pressurized pumping system included pump rotational speeds of 225, 255, 300, 330, 374, 420, 450, 525, 600, 675 and 750 and line pressures of 0, 1 and 2 kg cm^{-2}. An experimental set up was used for the study and the discharge pattern and discharge uniformity among delivery pipes was recorded and analysed statistically.

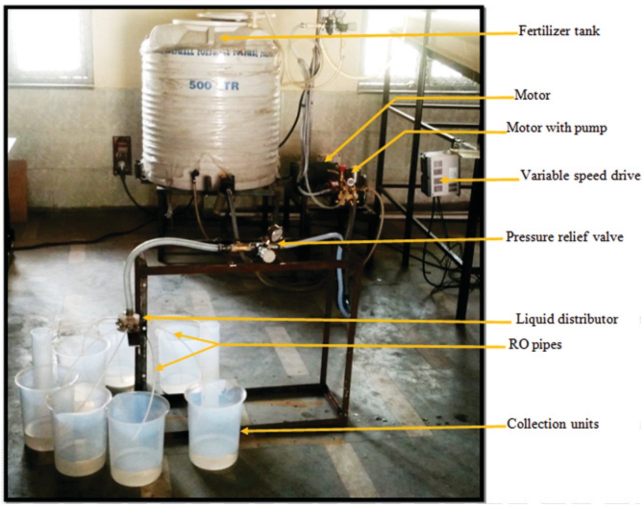

Fig. 3: Experimental set up for evaluation of liquid fertilizer metering

RESULTS AND DISCUSSION

Effect of pump speed and line pressures on pump flow rate

The flow rate of pump had to commensurate with the liquid fertilizer requirement in the field. The liquid fertilizer requirement for different basal doses of N application was ascertained. The required UAN flow rate in totality as well as for individual delivery pipe at 100% basal dose of N was determined through experimental setup. At a tractor forward speed of 1.23, 1.5 and 2 km/h, the required flow rate for 100 % basal dose of Nitrogen(@ 120 kg/ha) was 11.1, 13.5 and 17.96 $lmin^{-1}$, respectively. Pump was operated by motor at different speed controlled through variable frequency drive (VFD). In general, the flow rate from pump increased as the line pressure and the pump speed increased, Fig. 4. There was approximately 30-33 % increase in flow rate with increase in pressure from 0 to 1 $kgcm^{-2}$ whereas there was only 6-10 % increase in flow rates when pressure changed from 1 to 2 kg cm^{-2}. The flow rate varied linearly (R^2>0.98) with pump speed at selected pressure levels, Fig. 4.16.The pump flow rate of 6.68, 7.68, 8.32, 9.0, 10.20, 11.2, 12.1, 13.3, 14.41, 15.7 and 17.6 $lmin^{-1}$were obtained at pump speed of 218, 245, 289, 315, 356, 395, 421, 496, 569, 639 and 700, respectively in the absence of line pressure. At 1 $kgcm^{-2}$, the observed pump flow rates were 8.79, 10.14, 11.71, 12.56, 14.8, 16.5, 17.8, 19.8, 20.7, 21.8 and 23.4 $lmin^{-1}$ while at 2 $kgcm^{-2}$ pressure. The same were 9.32, 10.35, 12.05, 12.98, 15.3, 16.9, 18.3, 20.4, 21.3, 22.9 and 25.61 $lmin^{-1}$ at the corresponding pump speed in the same order, Appendix-P1, P2 and P3.For a flow rate range of 11.1- 17.96 l min^{-1}, the required pump speed was ranged between 245 to 421revolutions per minute. However, these flow rates could be achieved by different combinations of line pressure and pump speed. As the line pressure increased the flow rate of pump increased, but, at decreasing rate. The flow rate varied linearly (R^2>0.98) with pump speed at the selected pressure levels, Fig. 4.

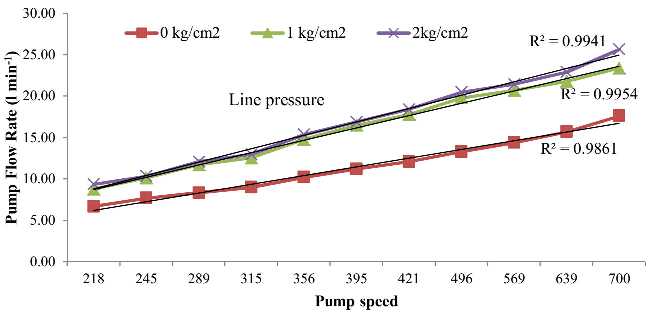

Fig. 4: Pump Flow rate affected by speed and line pressure

Effect of pump speed and line pressure on distribution uniformity of flow rates

The flow rates of liquid fertilizer through each delivery pipe were recorded and analysed for their uniformity distribution. A uniform flow rate by different tubes led to higher uniformity coefficient and uniform nitrogen placement. The distribution uniformity were in the range of 96.7 to 99.1 %, 96.7 to 99.5 % and 92.8 to 99.1 %at pressure levels of 0, 1 and 2 kg/cm^2, respectively at different pump speeds, Table 1. As flow pressure was increased from 0 $kgcm^{-2}$ to 2 $kgcm^{-2}$, the flow rate increased from 0.74l min^{-1} to1.04 l min^{-1}, 0.85 l min^{-1} to 1.15 l min^{-1}, 0.92 l min^{-1} to 1.34 l min^{-1}, 1.01 l min^{-1} to 1.44 l min^{-1}, 1.13l min^{-1} to 1.71l min^{-1} at pump speed of 218, 245, 289, 315 and 356, respectively in the same order.

The observations on evaluation of liquid fertilizer pumping system at different operational parameters revealed a significant effect of pressure and speed on flow rate. The volume of flow was controlled by varying the input speed to the piston pump and by use of ball valve as flow control valve. For controlling the pressure build up in the fertilizer metering system, pressure relief valve (PRV) was used.

Table 1: Mean flow rate and distribution uniformity among delivery pipes at different line pressure and pump speed

Pump speed	Line Pressure					
	0 $kgcm^{-2}$		1 $kgcm^{-2}$		2 $kgcm^{-2}$	
	Mean Flow rate through each pipe (l min^{-1}) Mean± SEm±	Distribution Uniformity among pipes (%)	Mean Flow rate through each pipe (l min^{-1}) Mean±SEm±	Distribution Uniformity among pipes (%)	Mean Flow rate through each pipe (l min^{-1}) Mean±SEm±	Distribution Uniformity among pipes (%)
218	0.74 ±0.020	97.3	0.97±0.011	98.9	1.04±0.038	96.3
245	0.85±0.020	97.7	1.13±0.056	95.0	1.15±0.027	97.6
289	0.92±0.021	97.8	1.30±0.043	96.7	1.34±0.097	92.8
315	1.01±0.034	96.7	1.40±0.037	97.4	1.44±0.005	96.5
356	1.13±0.032	97.2	1.65±0.025	98.5	1.71±0.015	99.1
395	1.23±0.016	98.7	1.83±0.014	99.3	1.88±0.063	96.6
421	1.35±0.019	98.6	1.98±0.008	99.6	2.05±0.056	97.3
496	1.48±0.027	98.2	2.21±0.011	99.5	2.28±0.037	98.4
569	1.62±0.024	98.5	2.31±0.018	99.2	2.38±0.027	98.9
639	1.74±0.016	99.1	2.42±0.012	99.5	2.55±0.062	97.5
700	1.97±0.022	98.9	2.60±0.062	97.6	2.85±0.039	98.6

CONCLUSION

Liquid fertilizer metering system constituted a pump, control valve and a distributor unit. Liquid fertilizer unit was designed and fabricated and was evaluated for their uniformity at different line pressures in laboratory and validated in field condition. The estimated UAN requirement was 340 and 170 lha^{-1} at 100 and 50 % basal dose of nitrogen in wheat. UAN was diluted with water in the ratio of 1:10, 1:12.5 and 1:20 for applying 100%, 80% and 50 % basal doses of Nitrogen, respectively. Experiment was conducted to know the flow rate of each distributor pipes at different line pressure and pump revolutions. The flow rate of pump increased as the pump speed and line pressures increased. More the pump speed of a piston pump; more IS the flow rate. Thus, the pumping system used for metering liquid fertilizer was capable to give a Flow rate variation of 0.74 l min^{-1} to 2.85l min^{-1} for different pump rpm. As the flow was restricted to increase the pressure, the flow rate increased at each pump rpm levels.

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