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DEVELOPMENT AND PERFORMANCE EVALUATION OF MOBILE IRRIGATOR FOR DRY LAND AGRICULTURE

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Abstract: This research work was conducted at Agricultural Engineering College and Research Institute, Kumulur located in Tamil Nadu, India. The mobile irrigator was developed for effective utilization of the available water in dry land agriculture instead of following the supplementary irrigation. In case of supplementary irrigation the application efficiency and distribution uniformity is less. It reduces both the yield of crop and the water use efficiency. Hence the aim of the present investigation was to develop a mobile irrigator which could be light in weight and can be moved manually while irrigating. Performance evaluation (application efficiency and distribution uniformity) of the irrigator was tested in a dry land field of maize. The results revealed an acceptable value of application efficiency (74%) and distribution co-efficient (75%). The travel speed and operating pressure were optimized about 2.1 $cm \cdot s^{-1}$ and 245 kPa. The crops for which the system can be used for irrigation are maize, groundnut, pulses, etc. For the efficient performance of the irrigator, the height of the crop should be less than or up to 1.5 m.

Key words: *Mobile irrigator, distribution uniformity, application efficiency, dry land agriculture*

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INTRODUCTION

Water is one of nature's precious gifts to mankind. With out water there is no life on earth. The available water is declining day by day in India, this is due to the fast growth of population. In order to feed the growing population, agriculture should be improved and from the available land and water, more crops should be produced. Effective planning and utilization of available water resources is very important to meet the current growing demand. Therefore water management and increased crop production is very essential and crucial for the welfare of living beings. The productivity of the land need to be increased, so in order to do it, pressurised irrigation should be used. Sprinkler and drip system are the two types of pressurised irrigation system used in India. In the sprinkler irrigation system there are various types but most of the types are either fixed or difficult to move manually. Research studies conducted in India by various institutions have indicated that the water saving in micro irrigation is about 40–80% with a yield increase of 40-60% for various crops grown in different climatic regions.

The hand move portable lateral system is composed of either a portable or buried main line with valve outlets at various spacing for the portable laterals. This system is used to irrigate more area than any other system, and it is used on almost all crops and all types of topography. The disadvantage of the system is its high labour requirement [1]. [2] Conducted a research on the pressure required of a cable tow irrigation system and found that it is a good indicator of the energy needed to efficiently operate such a system. Self-propelled gun type traveller system is usually the most practical system for irrigating irregular shaped fields [3].

Properly designed irrigation systems can minimise the losses of water delivered to the plants. Water scarcity is one of the major problems in many places of Tamil Nadu as far as agriculture is concerned and also the cost of installation of various types of pressurised irrigation viz. sprinkler and drip irrigation system for any agricultural field. In addition to these difficulties, it was not flexible and the maintenance cost was also very high. So in order to overcome some of the above said difficulties of pressurised irrigation system, an effort was taken to design a farmer friendly system which would be of much use to the farmers.

The objective of this study was to investigate the effective utilisation of available water by applying in the form of spray (using raingun), to reduce the cost of installation of pressurised irrigation system and fabrication of portable irrigation system to irrigate the crop during critical conditions.

MATERIAL AND METHODS

The mobile irrigator consisted of a Rectangular frame, Pneumatic wheel, Wheel supporting frame, Riser, Riser supporting structure, Rain gun, Flexible hose and Cable and drum assembly as shown in Fig. 1.

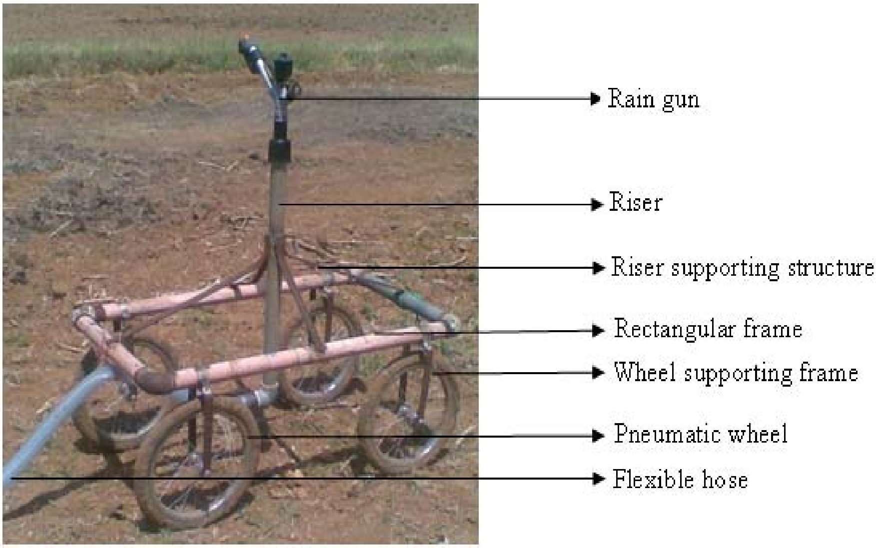

Figure 1. Mobile Irrigator

Rectangular frame

Rectangular frame is made by using galvanized iron hollow pipe material. A rectangular structure frame (100X50 cm) was fabricated. The irrigator moves in the field with the aid of a pneumatic wheel. Four numbers of pneumatic wheels were used. The rim, tier and tube used for this study were 40.64x3.18 cm type. Pneumatic wheel was attached to the main frame of the irrigator by means of an attachment called wheel supporting structure. Riser is the component of the mobile irrigator which was placed vertically at the centre of the rectangular frame. It was made up of galvanized iron pipe and its height was 1 m. It was placed at a height of 20 cm above the ground level. The riser consists of two threaded ends in order to attach rain gun at one end and hose at other end.

Riser supporting structure

The riser cannot be fixed to the frame directly. A supporting structure should be provided in order to attach the frame and also to fix it at a height of 20 cm above the ground level. A mild steel flat rod (1x0.25 cm) was used. The supporting structure was placed at an angle of 50^{o} to the horizontal frame and tag welded. Four pieces of supporting rods were used.

Raingun

A medium sized raingun was used. It nozzle diameter was 6 mm and similar to the two way sprinkler head. The throw length can be adjusted by a screw arrangement provided at the front of the nozzle. It goes a full rotation (360^{o}) when operated.

Flexible hose

The water was supplied from the main water source through the flexible hose to irrigator. The required pressure was created by using different hp motors. The flexible hose of 1.5” (3.75 cm) was used. The hose was connected to the riser through a hose nipple.

Cable and drum arrangement

The irrigator was dragged along the lane in the field manually by means of cable and drum arrangement. One end of the cable was fitted to the rectangular frame and the other end to a rotating drum. When the drum was rotated the cable wounded itself on the drum and by the means of that the irrigator moved in the field. The maximum length of the cable was 70 m. The drum and cable arrangement was mounted on a stand. The drum was rotated by means of handle which was fixed to the drum through the flat rod.

Testing done on Mobile Irrigator

Testing of the mobile irrigator was done at Cotton Research Station located at Veppanthattai in Perambalur district of Tamil Nadu, India. This place is rain fed area. The crop irrigated using the mobile irrigator was at the vegetative phase with two to three leaves per plant and the crop was in critical period under water stress. Soil type at that place was black soil and moisture retaining capacity of the soil was high because of which the crop survived for many days without irrigation. Availability of water is very less so, the water must be effectively utilized. The area under which the crop was raised about one ha. In order to irrigate such large field by any of the surface irrigation method even for a smaller depth the irrigation water requirement would be high and the losses also would be high.

The steps carried out in collecting the data for the calculation of application efficiency and distribution uniformity are as follows:

The mobile irrigator was placed in the field at one end and drum and cable was placed at other end. The flexible hose was fixed at the inlet and to the riser. The length of run was measured and the area to be irrigated was also found. The catch cans were placed at the centre of each run length perpendicular to the lane. The cans were placed at 1 m interval. The system was started and water was collected. The inlet and outlet pressure was measured using a pressure gauge. The time taken to cover the run length was noted. The amount of water collected in the catch can after each run along a single lane was measured and noted. After covering a single lane the irrigator was transferred to the next lane and same procedure was followed. This was done to show the percentage of overlap.

The amount of water collected was measured using a measuring cylinder. The volume was converted into depth of water collected by calculating the can surface area.

$$Depth\ of\ water\ collected\ (cm) = \frac{V}{A} \tag{1}$$

Where:

V [cm^3] - volume of water collected in catch can,
A [cm^2] - catch can surface area.

Tests were carried out on the mobile irrigator to find out the two main parameters. The parameters calculated were distribution uniformity and application efficiency.

Distribution uniformity

Distribution uniformity is a measure of how uniform the application of water is to the surface of the field. It was tested at different travel speeds (2.1, 3.2 and 5.5 cm per second) and operating pressures (195, 225 and 245 kPa). Mathematically, distribution uniformity can be represented as [5]:

$$DU = (Ave_{LQ} / Ave_T) \times 100 \tag{2}$$

Where:
DU [%] - distribution uniformity,
Ave_{LQ} [mm] - average of the lowest quarter of catch can readings,
Ave_T [mm] - average of all catch can readings.

Application efficiency

Application efficiency is a measure of how efficiently water has been applied to the root zone of the crop. This parameter relates the total volume of water applied by the irrigation system to the volume of water that has been added to the root zone and available for use of the crop. The application efficiency was calculated as [5]:

$$AE = \frac{\dfrac{Average\ depth\ applied\ (mm)}{100} \times area(ha)}{Water\ delivered\ to\ the\ field\ (ML)} \times 100 \tag{3}$$

Where:
AE [%] application efficiency.

Statistical analysis

Data analyzed using SPSS software. Data of experiment were analyzed by a randomized block design using factorial arrangements of treatments. The analysis of data was performed on each dependent variable using the treatments were compared for significance with ANOVA.

RESULTS AND DISCUSSION

Distribution uniformity

Distribution uniformity was calculated from Tab. 1. It was quite acceptable at 75%, although uniformities in excess of 80% are achievable. Table 2 showed that, F values of distribution uniformity are significant (ρ< 0.01) in travel speed and operating pressure. Travel speed of the irrigator can be adjusted to apply varying amounts of total irrigation. The amount of irrigation applied to an area at one time can be varied by adjusting travel speed. High uniformity distribution achieved at a travel speed of 2.1 cm per second at 245 kPa as compared to 3.2 and 5.5 cm per second. Uniform irrigation is important to ensure maximum production and minimum cost. The value of this parameter decreases as the variation increases. Non uniformity of the applied water can significantly affect irrigation performance [4]. A distribution uniformity of 100% would mean that each and every point with in the irrigated area received the same amount of water.

Table.1. Depth of water applied

Can spacing [m]	*SYSTEM EVALUATION*		*Depth applied [mm] (in ascending order)*
	Depth applied [mm]	*Depth applied [mm]*	
1	*18*	*1.2*	*1.2*
2	*26*	*1.7*	*1.6*
3	*32*	*2.1*	*1.7*
4	*40*	*2.6*	*1.9*
5	*46*	*3.0*	*2.1*
6	*46*	*3.0*	*2.3*
7	*46*	*3.0*	*2.6*
8	*46*	*3.0*	*2.6*
9	*48*	*3.1*	*2.7*
10	*42*	*2.7*	*2.7*
11	*40*	*2.6*	*2.7*
12	*44*	*2.9*	*2.9*
13	*46*	*3.0*	*2.9*
14	*48*	*3.1*	*2.9*
16	*44*	*2.9*	*2.9*
17	*46*	*3.0*	*3.0*
18	*50*	*3.2*	*3.0*
19	*56*	*3.6*	*3.0*
20	*50*	*3.2*	*3.0*
21	*50*	*3.2*	*3.0*
22	*56*	*3.6*	*3.0*
23	*48*	*3.1*	*3.0*
24	*48*	*3.1*	*3.0*
*25**	*70*	*4.5*	*3.1*
*26**	*72*	*4.7*	*3.1*
*27**	*68*	*4.4*	*3.1*
*28**	*70*	*4.5*	*3.1*
*29**	*66*	*4.3*	*3.1*
30	*48*	*3.1*	*3.1*
31	*48*	*3.1*	*3.1*
32	*48*	*3.1*	*3.1*
33	*48*	*3.1*	*3.1*
34	*44*	*2.9*	*3.1*
35	*42*	*2.7*	*3.1*

36	*44*	*2.9*	*3.1*
37	*48*	*3.1*	*3.1*
38	*50*	*3.2*	*3.1*
40	*48*	*3.1*	*3.2*
41	*46*	*3.0*	*3.2*
42	*48*	*3.1*	*3.2*
43	*48*	*3.1*	*3.2*
44	*50*	*3.2*	*3.2*
45	*50*	*3.2*	*3.2*
46	*52*	*3.4*	*3.4*
47	*48*	*3.1*	*3.6*
48	*48*	*3.1*	*3.6*
49	*46*	*3.0*	*4.3*
50	*42*	*2.7*	*4.4*
51	*36*	*2.3*	*4.5*
52	*30*	*1.9*	*4.5*
53	*24*	*1.6*	*4.7*
54	*24*	*1.6*	*4.7*

** These values indicate the catch cans in which overlap occurred*

Table.2. Variance analysis of distribution uniformity

Distribution Uniformity			
Variables	*df*	*Mean Square*	*F*
Travel Speed (S)	*2*	*311.50*	*97.95***
Operating Pressure (P)	*2*	*203.78*	*48.51***
*S*P*	*4*	*190.64*	*29.26***
Total	*8*	*-*	*-*

***p is significant at 0.01 levels.*

Distribution uniformity is primarily influenced by the system design criteria. Poor uniformity of application is often easily identified by differences in crop response and evidence of surface water logging or dryness. Because of obvious nature of the crop effects associated with poor distribution uniformities, increasing the uniformity is often seen as a strategy to improve crop yield rather than provide water savings. However, poor distribution uniformity does suggest that there is more likelihood of localized over-irrigation and hence, improvements in uniformity are commonly necessary as a precursor to direct water application efficiencies. It should be noted that distribution uniformity is calculated over the actual irrigated area and not the irrigable area. This means that distribution uniformity data must be considered for whole wetted area and not just within the boundaries of the crop being irrigated.

Non-uniformity of irrigation application will result in some sections of the field being over or under watered. While the average depth of water applied to a total given area may be known, one half of the total area will have received less than the average applied while the other half will have received more water than the average. In this case the half receiving more than the average may suffer from inefficiencies due to water logging or run-off, while the half receiving less than average may suffer from water stress. Often, if the non-uniformity is quite significant, this over or under watering is visible in the growth of the crop. Research indicates that distribution uniformity is affected not only due to the operating pressure and traveller speed but also due to the variations in the wind throughout the duration of the run. Wind drift and droplet evaporation losses can be large if the sprinkler design or pressure produces a high percentage of very fine droplets [4]. This conforms the finding of present study.

Application efficiency

The application efficiency of 74% was quite good and high efficiencies are typically hard to obtain with mobile irrigator but it is high as compared to surface irrigation system which ranges from 45-65% [4]. Table 3 shows that, F values of travel speed are significant ($\rho < 0.01$) for application efficiency. This table showed F values of operating pressure are significant in $\rho < 0.01$ for application efficiency. The interaction between travel speed and operating pressure are also significant in $\rho < 0.01$.

Table.3. Variance analysis of application efficiency

Application efficiency			
Variables	*df*	*Mean Square*	*F*
Travel Speed (S)	*2*	*188.53*	*89.73***
Operating Pressure (P)	*2*	*60.99*	*18.97***
*S*P*	*4*	*49.15*	*11.84***
Total	*8*	-	-

***p is significant at 0.01 level.*

The graph is plotted between depths of water collected in the catch can and can spacing (Fig. 2). This graph shows 15% overlap and depth of water collected decreases from centre to periphery. The graph infers that depth of water applied is more at the centre of the field than at the field boundaries. Application efficiency takes into account losses such as spray drift, evaporation, runoff, deep drainage and application of water outside the target crop area. Of these factors, deep drainage and runoff are probably the largest causes of inefficiency and generally due to over irrigation. Because of the losses during application, water application efficiency is always less than 100% [4]. Higher rate of irrigation can result in runoff and erosion on soils that have a slow intake rate. Whenever more water is applied than the water requirement of the crop, water is wasted and efficiency is low. Raingun that was used covers an area of about 1 acre when operated at a pressure of 245 kPa but it covers only 0.7 acre at a pressure of 195 kPa. Reducing the pressure at the raingun increases average droplet size and therefore, potential soil compaction. Application rate may be increased, leading to increased runoff. The total amount of water applied is affected by lane spacing, sprinkler capacity and irrigator travel speed [3].

The crop spacing should be regular and separate lane should be provided for irrigator to travel and irrigate the field. If there is insufficient spacing or no provision of separate lane for irrigator to travel the crop damage will occur. The system had some difficulties like, being a pneumatic wheel it gets struck in the field when the field becomes wet, when the irrigated soil contains more clay content. When the clay content was high it caused slip of the wheel during wet condition and a layer of soil was adhering on the wheels, which lead to more force requirement to pull, causing sometimes drudgery.

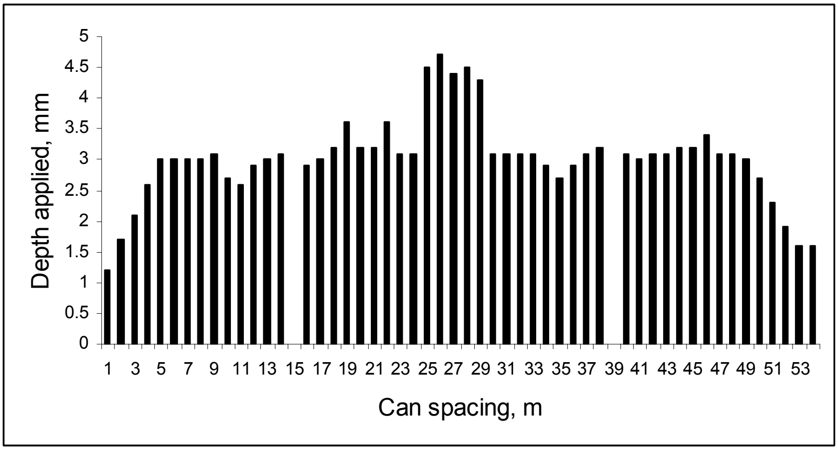

Figure 2. Combined distribution pattern

A half way rotating raingun viz. 180° rotating type can be used instead of a full rotation raingun viz. 360° rotating type which was used now. This can be done to enhance more complete coverage of the field.

CONCLUSIONS

The mobile irrigator which was developed found helpful in using the available water effectively with satisfactory value of application efficiency (74%), distribution uniformity (75%) and the time consumption was also acceptable. It is suitable to irrigate the dry land cultivated area or area needing supplemental irrigation. The height of the crop for which the system to be used should be short or medium height about 1.5 m. The height of the crop when increases above 1.5 m the irrigator cannot be used. This irrigator is difficult to move from field to field. It may be possible to substitute other types of irrigation systems, but for some farmers and some applications, the mobile irrigator is still the most economical machine when initial cost, operating cost and labour required are considered.

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RAZVOJ I OCENA PERFORMANSI MOBILNOG UREĐAJA ZA NAVODNJAVANJE U SUVOM RATARENJU

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Sažetak: Ovao istraživanje je sprovedeno na Fakultetu za poljoprivrednu tehniku i Istraživačkom institutu Kumulur u Tamil Nadu, Indija. Mobilni uređaj za navodnjavanje je razvijen za efikasnu upotrebu dostupne vode u suvom ratarenju umesto dodatnog navodnjavanja. U slučaju dodatnog navodnjavanja smanjuje se efikasnost upotrebe i ujednačenost distribucije. To smanjuje i prinos i efikasnost korišćenja vode. Kako je cilj ovog istraživanja bio da razvije mobilni uređaj za navodnjavanje koj će biti lak i pogodan za ručno pomeranje tokom navodnjavanja. Ocena performansi (efikasnost navodnjavanja i ujednačenost distribucije) uređaja su testirani na suvom polju kukuruza. Rezultati su pokazali prihvatljivu efikasnost navodnjavanja od 74% i koeficijent distribucije od 75%. Brzina kretanja i radni pritisak bili su optimizirani na oko 2.1 $cm \cdot s^{-1}$ i 245 kPa. Sistem može biti upotrebljen za navodnjavanje kukuruza, kikirikija, mahunarki i sl. Za postizanje efikasnog navodnjavanja visina useva treba da bude do 1.5 m.

Ključne reči: *pokretni uređaj za navodnjavanje, ujednačenost distribucije, efikasnost primene, suvo ratarenje*

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