DEVELOPMENT AND EVALUATION OF A PULSATING MICRO-SPRINKLER IRRIGATION SYSTEM

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PROJECT REPORT

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Tavanur - 679573
Malappuram

1992

DECLARATION

We hereby declare that this project report entitled **'DEVELOPMENT AND EVALUATION OF A PULSATING MICROSPRINKLER IRRIGATION SYSTEM'** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this Project report, entitled ***"Development and Evaluation of a Pulsating Micro-Sprinkler Irrigation System"*** *is a record of project work done jointly by* ***Bindu P.K., Morris K. George, Sreevidya H. and Vishnu B.*** *under my guidance and supervision and that it has not previously formed the basis for the award of any Degree, Diploma, Fellowship or Associateship to them.*

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NOMENCLATURE

Term	Symbol	Definition
Average application rate of irrigation device	Iav	Expressed as total amount of water, VT divided by total irrigation time, T_c mm/hr.
Application rate of irrigation device	Isp	Expressed as the discharge of irrigation device divided by its wetted area, in mm/hr.
Number of pulses	n	The number of operating phases or the number of cycles, the last cycle consisting of only the operating phase.
Pulsation rate	P	Defined as ratio between real irrigation time, t_i in single pulse to total time of single pulse, t_o
Number of stations per set	S	It is the number of valves connected to a single pulsator
Total irrigation time	T_c	It is the total time during which the irrigation is applied, in hours.
Resting time in single pulse	t_b	It is the time in a single pulse during which water is not applied, in hrs.
Total time of single pulse	t_c	It is the total time of a single pulse including the operating phase and resting in hrs.
Real irrigation time in single pulse	t_i	Defined as the real irrigation time in a single pulse during which irrigation system operates in hrs.

Term	Symbol	Definition
Total amount of Water applied	V_T	It is the total amount of water applied in a time of T_c, in mm.
Ratio I_{av}/I_{sp}	R	Ratio between average application rate I_{av} and application rate of irrigation device I_{sp}
Ratio t_i/t_b	y	It is the ratio between real irrigation time in single pulse and resting time in single pulse.
Distribution characteristic	Dc	Defined as the ratio of the area which receives more than half of the average application to the total wetted area, expressed as a percentage.
Absolute maximum application depth	D_{xa}	Defined as the greatest depth caught in any of the containers for a particular emitter.
Effective maximum application depth	D_{xe}	Defined to be the average depth caught in the 5% of the containers that had greatest catch depths.
Mean application depth	D_a	Defined as the average depth of water caught in the containers located within a distance of R_e from the emitter.
Effective radius	R_e	Defined as the average distance from the emitter to the most distant 5% of containers which received water.
Effective area	A_e	It is the circular area within a distance of R_e from the emitter
Coefficient of variation	C_v	It is calculated by dividing the standard deviation of the depths used to calculate the mean by the mean application depth and is expressed as a percentage.

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SYMBOLS AND ABBREVIATIONS

A	Ampere
ac	Alternating Current
Agric	Agriculture
ASAE	American Society of Agricultural Engineers
ASCE	Amercian Society of Civil Engineers.
Cm	Centimetres
Co	Company
dc	Direct Current
Dept	Department
dia	diameter
Ec	Electrical Conductivity
ET	Erapotranspiration
et al	and other people
F	Farad
fig	Figure
HDPE	High density poly ethylene
hp	Horse Power
hr	hour(s)
Hz	Hertz
IC	Integrated circuit
in	inch(es)
Inc	Incorporated
IS	Indian Standard
K	Kilo
kg	Kilogram
Kpa	Kilo pascal
LED	Light Emitting Diode

lit	Litres
LLDPE	Linear low density poly ethylene
lph	litres per hour
lps	litres per second
Ltd	Limited
M	Mega
m	metres
mA	milliampere
mm	millimetre
mm/hr	millimetres per hour
no.	number
pp	pages
p.s.i	Pounds per square inchs
PVC	Poly vinyl chloride
Pvt.	private
s	seconds
Vol.	Volume
°	Degree
'	minutes
"	seconds
Ω	ohms
μ	micro
%	percentage

INTRODUCTION

India is the seventh largest and second most populous country in the world. Agriculture is the principal occupation of more than 70 percent of the people and it contributes more than 50 per cent of the Gross National Product (GNP). But even after forty five years of independence, the country's agriculture scenario has not developed to fulfil the needs of the population. Our development and life patterns have also led to an erosion of our natural life-support systems. Of the many factors in the agriculture field, though irrigation has received a great fillip after independence, the progress, especially in arid and semi-arid areas of the country, is not upto the mark. Successful agriculture is not practicable in many of these areas due to uneven distribution of rainfall. It goes without saying that low yields are due mainly to uncertain rains during the growth period of crops.

Irrigation, an age-old device of watering the soil, is defined as 'the application of water by human agency to assist the growth of crops, grasses and trees'. Human efforts to fight against nature's niggardliness in the supply of water to agriculture, takes the form of irrigation in the first attempt, the main function of which is to nullify the adverse impact of irregular, uneven and inadequate rainfall with its wide fluctuations. It averts severe and semi-famine conditions and supplements the supply of rain water. However the demand of water for irrigation has greatly outstripped its availability. Unless we increase the productivity of our resources and raise the input-use efficiency based on the scientific principles of management, and judicious use of inputs like irrigation water, the hope of ensuring equity with growth in the eighth plan period would prove illusory.

The most pressing problem of our country is the food problem. This problem has specially become acute due to the increasing mismanagement of the available water and an everincreasing population. To solve this, the productivity of the land, both by intensifying the land use and by increasing the crop yields per unit area, will have to be increased. In India, irrigation is mostly done by traditional surface methods of irrigation like wild-flooding, borderstrip method and check-basin method. But these methods require large amount of levelling, which increases the cost of irrigation considerably. Studies have shown that 45-65% of the irrigation water is lost due to seepage and run-off, in these methods. The other draw backs of the surface methods are low areation due to flooding and that saline water cannot be used for irrigation. Water is a precious input. Its excessive use is not only wasteful, but often depresses crop yields. Water use should be based on crop needs, especially at critical times of rapid vegetative growth, flowering and seed setting. So the efficient management of water is the need of the hour. Modern agriculture technolcgy is based on sufficient moisture conditions. It is in this context that new irrigation techniques like sprinkler irrigation and drip irrigation become relevant.

Sprinkler irrigation and drip irrigation are versatile means of applying water to any crop, soil and topographic condition and they are known for water-saving and uniform application of measured quantity of water. Fertilizers, pesticides and soil amendments may be dissolved in water and applied through the irrigation system. This reduces labour costs and may improve the effectiveness and timeliness of application. But each of these methods has its own demerit also. In sprinkler irrigation, losses due to overirrigating and outirrigating at plot margins amount to about 20%. In drip irrigation, this problem is solved but the clogging of emitters and the limited root growth of the crop become the great disadvantages.

The microsprinkler system combines the advantages of the drip and the sprinkler system and avoids most of their disadvantages. The system distributes water in the form of a fine rain-like shower. Generally, the water is transferred to the filed through a net-work of tubes and is then applied to the plants using micro-sprinklers achieving localised irrigation. Although micro-sprinkling is used primarily for the application of water to crops, it is a multi-purpose system with a wide range of uses, such as fertiliser and herbicide application, frost protection and cooling of green houses. In tests done by the Israeli Agricultural Extension Service, the irrigation efficiency of micro-sprinklers - 94% to 97% - was found to be higher than that of any other irrigation method tested. This was attributed to the uniform wetting of the irrigation area and to the correct amounts of water applied.

With micro-sprinklers, the amount of water required by the plants is applied to a given volume of soil. This enables the root system to develop evenly and to spread densely throughout the volume of wetted soil, thus ensuring the supply of water and nutrients to the tree. This serves as an advantage over the drip irrigation system, because the roots of the drip irrigated trees will be concentrated in a shallow, small volume of soil under the dripper. In the case of crops that are mainly rainfed and need only supplementary irrigation for relatively short (2-3 months), but critical periods of time, the root system develops according to the natural rainfall and only the micro-sprinkler - with its modular design and wide range of options - is capable of supplying the required quantity of water and nutrients accurately and efficiently to the already developed root system. "Micro-sprinklers with its larger diameter wetting pattern is especially desirable in areas with coarse-textured soils were lateral movement of soil water is limited. The greater coverage diameter results in greater soil moisture reserve and also provide advantages when the system is used to apply herbicides, fungicides, nematacides or fertilizer. The uniform irrigation rate of micro-sprinklers makes it easy to calculate the amount of water needed for each tree. With a low irrigation rate, there is no run-off probelm or water ponding on the soil surface. By applying the right amount of water at the correct irrigation rate, there will be no seepage beyond the root-zone caused by water logging. Micro-sprinklers wet only about 40-80% of the soil surface in a mature orchard. The area wetted by the micro-sprinklers can be adjusted according to the development of the root system without any additional expense. The shape of the wetted surface can also be changed from full circle to a half-circle or a strip shape.

Micro-sprinklers are connected to the laterals by a flexible tube, enabling the underground installation of the distribution pipes. This helps in preventing damage caused by birds and rodents. Visual inspection of the micro-sprinkler is simple and fast. Less time is required for the inspection of micro-sprinkler than it is for the inspection of the several emitters per tree in a drip irrigation system. A large mesh filter screen used in micro-irrigation allows for longer operating time between cleanings. Micro-sprinklers are also superior to other irrigation systems on marginal land and in the use of marginal, or saline irrigation water. According to a study conducted in Israel, the yield of the seven year old apple orchard using micro-sprinklers was 15 to 30% higher, and of better grade than that of the drip irrigated plot. Also it was shown that the salinity level in the root-zone was lower under micro-sprinklers than under drippers.

Irrigation with low application rates was found desirable for optimal plant-soil-water relationships in regard to plant response to soil moisture regime and water movement in the soil profile. Studies have shown that the application rate needed to wet most soils directly to a water content lower than the maximum value above which oxygen diffusion through the soil in inhibited, is in the range of 0.5-2mm/hr. None of the available water emitters is capable of applying, water at such low application rate. The pulsed water application principle was developed in order to obtain the desired low application rate from any water emitter. It is based on a series of pulses where each pulse is composed of the operating and resting phases. Irrigation in the first phase is carried out with a relatively high precipitation rate; however, when the time of resting phase is taken into account, the average precipitation rate is relatively low. The higher precipitation rate reduces the risk of clogging. In pulsating micro-sprinkler irrigation the higher application rate in the operating phase and higher operating pressures further reduces the risk of clogging. So the pulsating micro-sprinkler system serves the purpose of closely matching available water resources with the water requirements of crops and provides for a better soil-plant-water relationship.

The study was done under the broad objectives of

1) To evaluate the performance characteristics of different micro-sprinklers and
2) To design and develop a pulsating micro-sprinkler irrigation system.

The specific objectives of this study were,

1. To evaluate the distribution pattern of selected micro-sprinkler heads at different operating pressures.
2. To determine the distribution, characteristic and coefficient of variation of different micro-sprinkler heads under different pressure heads.
3. To evaluate the discharge flow rate, wetted diameter and application rate for different micro-sprinkler heads under different pressure heads.
4. To design and develop a pulsating micro-sprinkler irrigation system and to test it.

REVIEW OF LITERATURE

In many areas of the world the amount and timing of rainfall are not adequate to meet the moisture requirement of crops. Irrigation is essential to raise crops necessary to meet the needs of food and fibre. The increasing need for food production for the growing population is causing the rapid expansion of irrigation throughout the world. To obtain highest productivity with minimum water and least disturbance to the ecosystem scientific irrigation practices such as micro irrigation are to be followed.

2.1 Micro - irrigation

Micro-irrigation is defined as an irrigation method that applies water to less than 100% of a crop area. This includes drip, micro -jet and Micro-sprinkler irrigation systems. Micro-sprinkler irrigation is a versatile means of applying water. The design principles are similar for Micro-sprinkler and trickle systems (Richard H. Cuenca, 1989).

2.2 Micro -irrigation Development

The very first experiment in Micro -irrigation was started in Germany in 1860 using clay pipes as a combination of irrigation and drainange systems. Later porous pipes and canvas were used for irrigation and in late 1940's plastic pipe micro-irrigation system was used to irrigate green house in U.K. By early 1960's plastic pipe micro-irrigation systems were extensively used in U.S. to irrigate green house plants.

Modern day surface trickle irrigation technology dates back to 1960's when Simca Blass, an engineer developed and used this technology in 1963 in Israel. Micro-sprinkler irrigation system has been designed as an improvement over the trickle irrigation system. This has been developed at the beginning of 1980's and it offered many advantages over trickle irrigation .

Micro-irrigation is becoming a popular irrigation method for vine and tree crops in many areas of the country. (Brian. J. Boman, 1989). In situations where root system develops according to the natural rainfall, such as in the banana plantations in Northern Australia, Central America and many Asian countries, only the micro-sprinkler with its modular design and wide range of options-is capable supplying the required quantity of water and nutrients accurately and efficiently to the already developed root system.

2.3 Advantages of Micro-sprinkler System.

2.3.1 Water Conservation

Considerable saving in water will result in going for micro-sprinkler irrigation system . Micro-sprinklers wet only about 40 to 80% of the soil surface in a mature orchard. The area wetted by the micro-sprinkler can be adjusted according to the development of the root system.

Christeinsen (1942) has estimated that direct evaporation from the spray itself when normal pressure is applied in a normal wind velocity condition did not exceed two percent. Dev Nir (1982) reported that in green houses, sprinkling irrigation not only provides water, but also regulates air humidity, temparature etc.

In conventional sprinklers larger droplets having higher kinetic energy disrupt the soil surface causing reduced infiltration rate due to crusting (Diado and Wallender, 1985). This phenomenon does not appear to be a concern for microsprayer emitters because of their smaller droplet size. This prevents water loss by run off. Providing too much water results in anaerobic conditions within the root zone while insufficient water inhibits root expansion and photosynthetic capacity (Wierenga and Sadiq,1985) Micro sprinklers applies the right quantity of water only.

The gradient for moisture movement off the crop is decreased during irrigation and the plant transpiration rate will decrease to low and even negligible levels . However, from the perspective of the air mass in the boundary layer above the crop, the gradient of watervapour movement is being supported by the evaporation off the sprinkler droplets. The plant itself is not feeling stress because it is within an envelope of high relative humidity just as would be the case if it were freely transpiring.

(Richard H.Cuenca, 1989) . Thus the water evaporated from the micro sprinklers reduces the rate of ET of plants.

Micro sprayer emitters have a low precipitation rate which typically are less than 3mm per hour. Thus by applying the right amount of water at the correct irrigation rate, there will be no seepage beyond the root zone, nor problem of aeration in the root zone, caused bywater logging (L.A. Chaya and D.J. Hills, 1991.)

The shape of the wetted surface can be changed from full circle (small for young trees and progressively larger circles as the trees develop) to a half circle or strip's . Hence water needed to wet unwanted portions of the field is saved (Anonymous, 1992.)

2.3.2 Irrigation efficiency.

In tests done by the Israeli Agricultural Extension service, the irrigation efficiency of micro-sprinklers -94% to 97% - was found to be higher than that of any other irrigation method tested. This was attributed to the uniform wetting of the irrigation area and to the correct amounts of water applied. Because of high irrigation efficiency less time is required to supply the required quantity of water, thus saving in energy.

With micro-sprinklers, the amount of water required by the plants is applied to a given volume of soil and this enable the root system to develop evenly and to spread densely throughout the volume of wetted soil, thus ensuring the suply of water and nutrients to the tree. With low irrigation rate, there is no runoff problems or water ponding on the soil surface. The irrigation rate can be easily matched to the soil and climatic conditions. The uniform wetting of the whole soil volume makes it easy to use all types of soil moisture monitoring devices. All these are responsible for the higher irrigation efficiency of micro-sprinklers.

2.3.3 Agrotechnical advantages.

Micro-sprinklers are connected to the lateral by a flexible tube, enabling underground installation of the distribution pipes. This helps in preventing damage caused by birds and rodents. A larger mesh filter screen used in micro-irrigation allows for longer operating time between cleanings Micro-sprinkling will also permit the introduction of fertilizers into the irrigation water, which helps to facilitate the fertigation process. This results in lower labour requirements and higher fertilizer efficiency. Fertilizers are applied directly to the root zone and the timing can be adjusted to the varying seasonal demand of the trees. Although micro-sprinkling is used primarily for the application of water to crops, it is a multi-purpose system with a wide range of uses, such as fertilizer and herbicide application, frost protection, and the cooling of green houses.

2.3.4 Yield.

The final goal of any irrigation system is to increase the yield of high quality fruit. Micro-sprinkler irrigation is capable of improving the physical condition of the soil and thus will enhance the yield to a great extend.

In the Arava deserts of Israel (1991) about 24 million tonnes, of tomato per hectare could be produced by micro-irrigation. When tried on an apple orchard in Israel, micro-sprinklers caused an increase in yield of 15-30% than with drip irrigation.

2.4 Comparison with other irrigation systems.

The micro-sprinklers are operated at a higher pressure of about 1.5 kg/cm^2 as against the low pressure used in drip systems . Hence clogging is considerably reduced. Visual inspection of the micro-sprinklers is also simple and fast. Less time is required for the inspection of a micro-sprinkler than it is for the inspection of the several emitters per tree in a drip irrigation system.

It is well known that root distribustion patterns itself on water distribution in the soil. In a field trial comparing micro-sprinkling with drip irrigation, in a seven year old apple orchard located in Israel, root patterns were significantly different under the two irrigation systems. The micro-irrigated roots were evenly distributed in the wetted soil volume and the number of roots per tree were much greater. Roots of the drip irrigated trees were concentrated in a shallow, small volume of soil under the dripper, whereas under micro-irrigation a large number of roots penetrated to depths of 70 to 80 cm. The canopy |active root relationship was also much better under micro-irrigation.

Micro-sprinklers are also superior to other irrigation systems on marginal land and in the use of marginal, or saline, irrigation water. This was demonstrated in a trial on shallow, stony land in Israel. The yield of the seven year old apple orchard using micro-sprinklers was 15 to 30% higher, and of better grade, than that of the drip irrigated plot.

In an Israeli experiment on heavy soils irrigated with saline water (EC 2.8mmhos) ,it was shown that the salinety level in the root zone was lower under micro-sprinkler than under drippers.

In the case of water-sensitive crops, where wetting of the upper portions of the plant is undesirable, micro-sprinkler irrigation can be used, as it is an under-the -canopy irrigation method. In such cases ordinary sprinkler are installed at a lesser height of 15-30 cm above the ground surface. So the wind effect is considerably less due to shielding bythe canopy and lesser wind-velocities near to the ground . So wind-drift losses are lesser when compared to conventional sprinkler irrigation.

2.5 System Performance.

Spray emitters usually have slotted caps or deflector plates which typically distribute water in distinct streams. Spinners use a moving part which rotates to disperse the water stream over the wetted diameter.

The extend of the wetted zone in micro-irrigation is determined by the spacing of the sprinkler heads and is a function of the soil type. (Keller 1975) Johnston

(1981) reported on the flow rates and the wetted diameter of seven spray emitters and two spinner emitter. He determined that the actual coverage pattern for several emitter model varied considerably from the manufactures specifications.

Greater emphasis should be placed on improving crop production in humid climates, where water use efficiency is inherently greater than in other regions (Sindair et al., 1984.) Furnishing a suitable moisture regime for superior plant performances is contingent on knowing the appropriate microhead spacing.

Micro-irrigation spray and spinner emitters are characterized by, as having operating pressure of less than 207 Kpa (30 psi), discharge rates in the range of 20 to 100 lph (15 to 25 gal|h) and throw diameters ranging from 1.5 to 10m (5 to 30 ft.) (Post et al 1986).

Brian J Böman (1989) studied the distribution pattern of micro-irrigation spinner and spray emitters at the University of Florida's Agricultural Research and Education Centre at Fort Pierce using the American Society of Agricultural Engineers standard. ASAE S 330. The standard recommends the sprinklers to be 0.6 m (2 ft.) above the catch containers. However, typical micro-spsrinkler emitters are installed in tree crops on stake assemblies 0.15 to 0.3 m (6 to 12 in) above the ground. Therefore, the tests, were conducted with emitters positioned on stake assemblies 200 mm (8 in) above the tops of the catch cans. He designated a new term which appropriately described the wetted area. This was accomplied by defining the term " effctive radius" (Re) to be the average distance from the most distant 5% of containers which received water. The effective area (Ae) of water applications by the emitter was then calculated as the circular area within a distance of Re from the emitter. The Re's ranged from 1.7 to 3.5m for the emitters tested.

2.5.1 Droplet size

The water droplet size is an important consideration in the design of sprinkler irrigation systems. Small droplets are easily lost due to wind drift and evaporation (Kohl and De Boer, 1984.) Drop size can therefore, affect the extent of wind distribution of the spray pattern which in turn affects both uniformity of coverage and irrigation effeiciency.

The parameters affecting droplet diameter are

1. Operating pressure Khol (1974) determined that higher pressure for a fixed nozzle size promoted smaller d oplets over the entire application profile..
2. Geometry of the spray plate surface. Kohl and Boer (1984) observed that for low pressure spray-type agricultural sprinklers, the geometry of the spray plate surface, rather than the nozzle size and operating pressure, was the dominent parameter that influenced drop size distribution. In the same study, it was determined that smooth plates produced smaller droplets than coarse, grooved plates.
3. Nozzle size and geometry, Dadioa and Wallender,(1985) found that volume weighted mean droplet diameter increased for noncircular nozzles compared to circular nozzles. Additionally, they observed that droplet

diameter increased with nozzle size.

L.A. Chaya & D.J. Hills (1971) utilized a laser probe instrument to determine droplet size distribution from micro-sprayer emitters. Measured volume mean droplet diameter for all tests ranged between 0.25 mm and 0.71 mm . Difference in droplet size distribution were found with changes in pressure, nozzle size and impact plate geometry.

2.5.2 Uniformity.

The irrigation efficiency of micro-sprinklers will depend upon the degree of uniformity of water application. The water spray distribution characteristics of the emitters and their spacing will regulate the uniformity of water application. The spray distribution characteristics of sprinkler heads are typical and change with nozzle and operating pressure.

Keller and Karmeli (1974) introduced the coefficient of manufacturing variation (CV) as a statistical measure of manufacturing variation in irrigation emitters. CV is a dimensionless value calculated by dividing the standard deviations of the flow rates of a suitable sample of emitters by the mean flow rate of the sample tested.

Unlike impact sprinkler, micro-irrigation emitters generally are located in the field with non overlapping patterns on widely spaced plants. Merriam and Keller's (1978) distribution characteristic (DC) is the standard method for evaluation for non overlapping sprinklers. The DC concept was developed before wide spread use of micro-irrigation in orchard and vine crops and it may not be applicable under these circumstances. The DC is defined as the ratio of the area which receives more than half of the average application to the total wetted area expressed as a percentage. They suggested that DC values greater than 50% are probably satisfactory and that very good patterns result with DC's greater than 66%.

Soloman (1979) presented the manufacturing variation for various single and multiple orifice type emitters used for micro-irrigation .These emitter types had a CV range of 0.02 to 0-07 for nine micro-sprinklers and micro-spray emitter models used for irrigation of tree crops.

Post et al (1986) recommended using additional performance indicators in addition to DC inorder to better characterize emitter performance . The CV of catch depth was selected as the primary performance indicator for this study.

Post et al (1986) examined six spinner type micro-irrigation emitter at a pressure of 172kpa (25 psi) . They concluded that application uniformity was much lowerfor the non overlapping micro-irrigation emitter than for overlapped sprinklers. All six of the emitters they evaluated produced poor ratings. when standard concepts of of uniformity coefficients used for sprinkler irrigation were applied.

The ASAE Engineering practice standard (EP 405-1) concerning performance of micro-irrigation systems (ASAE 1988) recommended the following CV range classifications .

0.05 is excellent, 0.05 to 0.07 is good, 0.07 to 0.11 is average, 0.11 to 0.15 is marginal and >0.15 isunacceptable.

Richard H. Cueala (1989) described the standard procedure for making a uniformity test for a single sprinkler. It involves settingup of a square grid with a minimum of 80 collectors within the wetted diameter. The minimum collector diameter is 80mm. The sprinkler to be tested is placed at the centre of the grid that is midway between 4 adjacent collectors, at a height of 0.6m above the average elevation of the tops of the four nearest collectors. The nozzle discharge pressure, sprinkle flow rate, and speed of rotation must be accurately measured. The test time recommended by ASAE S 330 1 (ASAE. 1985) is one hour.

Brian J. Boman (1989) reported that uniformity is an indicator of the equality (or inequality) of the application rates within the pattern diameter of an emitter. He reported that spinner type emitters had significantly higher distribution uniformitees than spray emitters and the CV values less than 100 for these types of emitters can be considered as "good" water distribution.

Brian J Boman (1989) had indicated that the spaghettitubing may significantly affect the overall lemitter assembly CV . He examined variations in flow uniformity specifically from the emitters. The CV for each location was calculated to determine effects of emitters on flow variation. He also investigated effects of spaghetti tubing on flow uniformity. Mean CV 's were 1.3 percentage and 1.6 percentage respectively for two microsprinkler models. Manufacturing variation of this magnitude are considered as excellent by ASAE standard. The emiters used on specific spaghetti tubes had very consistent discharge thereby implicating the spaghetti tubing as a major source of flow variations. The increase in cross sectional area and resulting decrease is friction losses resulted in a 12 percentage increase is emitter discharge rate.

He examined the micro-sprinkler assembly discharge variations to determine the contribution from the spaghetti tubing and that from the emitter itself. Spaghetti tubing diameter was found to significantly affect the discharge rate spaghetti tubing was found to be an important factor to consider in the overall uniformity of micro-sprinkler systems.

2.5.2.1 Pressure effects.

Kensworthy et al (1972) reported that if the pressure distribution along a lateral line can be determined, uniform irrigation can be achieved by adjusting the length and size of micro tubes used, by adjusting the size of emitters or by slightly adjusting the spacing between the emitters.

Hills et al (1986) reported the results of an experiment using oscillating pressure on two type of spinner emitters and two types of spary emitters. The results of that study showed that pressure oscillation on level terrain did not improve the distribution uniformity.

Uniformity of application depends on matching operating pressure with the selected sprinkler diameter, wind effects, and sprinkler spacing. If the pressure is too low, the water stream is not adequately broken up and a dounut-shaped application pattern results. If the pressure is too high, the stream is broken up into extensively small droplets and does not carry water to the extend of the design wetted diameter. (Richard H. Cuenla, 1989).

2.5.2.2 Effects of Wind

Wind distorts sprinkler patterns and causes uneven distribution of water. Considering micro-sprinklers this effect is less due to the shielding by the canopy and lesser wind velocites near to the ground.

A number of sprinkler studies have been conducted by Human and Kohl(1983) which relates wind to uniformity . The direction and speed of wind, height of risers, nozzle size and pressure turbulance in the stream of water entering and leaving the nozzle and jet angle were found to have an effect on sprinkler pattern distortion.

In sprinkler droplet studies, Von Berneth (1988) observed that wind drift was affected by dropsize distribution, water jet trajectory angle and wind velocity. Wind drift in young orchards irrigated by micro sprayers may greatly affect the irrigation efficiency since the small droplets may be flown away from the soil area encompassing the tree's roots.

Richard H. Cuenca (1989) reported that wind drift losses are fairly significant if the sprinkler nozzle are located high above the crop canopy where they are subjected to higher wind velocities than those that occur close to the canopy.

2.6 Components

The system consists of pump unit, control head, filter, mainline, submain, laterals and micro-sprinklers. The efficient working and performance of the system depends on the proper design of these components.

2.6.1 Pump unit

The pressure necessary to force water through the components of the system, including the fertilizer tank, filter unit main line, lateraland nozzle is provided by the pumping unit . The most common type used in sprinkler irrigation is a contrifugal pump (Michael, 1978, Sivanappan, 1987).

The factors that affect the size of the pump are the size and the shape of the irrigated area, topography, system discharges, cost of equipment, number of pumping hours per season, prices of electricity and the efficiency of the pumping unit.

2.6.2 Control head

The central control and operation point of the system consist of valves, discharge and pressure meters (means for control and regulation for discharges and pressures including no-return valves and air vents)and automation equipments and control. Each control head serves and controls an irrigation unit, having a unity of irrigation pattern and fertilizing regime . The unit size may vary and if the field is not too large; it will be operating from one control head as one unit, otherwise it may be divided into smaller units each with its oven control head, supplied by a main.

2.6.3 Filters

The filter is the most important part of the control head and the one that requires the greatest amount of care and maintenance . It should be efficient, easily washed, involving a minimum head loss and cheap. The strainer may be made of a perforated plate or of a wire mesh. Commercially available wire meshes, are 4,10,20,40,60,80,100,120,140,160, 200 and 300. Those used in micro irrigation are generally in the range 80 to 200. They are in most cases made in a cylindrical form , with water flowing either from within to out side, or from the outside to the inside.

ASAE (1980) reports that filter units used to prevent emitter clogging were widely recognised as the key to succesful operation of the micro-irrigation systems. Centrifugal filters, sand separators, vertical cyclones, gravel filters and screen filters are the generally used efficient filters.

2.6.4 Automation equipments

Automatic micro-irrigation ensures saving of work, time and precise application of water without the risk of forgetfulness. Automatic irrigation control along with automated irrigation scheduling helps to achieve very high application efficiency and higher yield since water stresson soil never exceeds the preset limit. In micro -sprinklers irrigation automation can be achieved in four levels.

1. Automatic shut off, usually by a clock, but much more preferably by means of a volumetric metering valve.

operation is started manually and the valve is preset for a given water quantity . Shut off is actuated by hydraulic action or sometimes electrically.

2. Follow through operation with a series of valves. All of these are preset to the required amounts and shut off of one valve opens the next one hydraulically or electrically until the complete cycle is finished.

3. Computer or control board operation which opens or close each valve hydraulically or electricall according to any predesigned programme or super impossed orders.

4. The system operated by tensiometer or other soil moisture potential sensors.

Tombesi L. and G. Favola (1975) developed a new electronic device for automation of irrigation system consiting of an atmometer and two elctro-optical indicators. One for measuring potential evapo-transpiration or evaporation and the other for measuring the amount of water distributed and possible rainfall. The device was radio controlled.

Naol. T (1975) developed an automtic irrigation system for mulberry fields. Evapotranspiration from mulberry orchardes is found equal to 1 to 1.5 times evaporation from a free water surface. This issued as the basis for making the apparatus. Field tests indicated that irrigated trees has 30% more leaves than non irrigated trees.

Maticic (1975) discribed about a tesio- meter control apparatus which consisted of mercury type tensio-meter and automatic relays and contacts. This was used to control stationary sprinkler irrigation systems according to soil water deficit.

Nosenko V.F. and A.N. Koayangin (1975) reported about a new apparatus for continuous micro-irrigation according to water requirement throughout their vegetative period. Average rate of sprinkling was limited to 0.01 to 0.002mm/minute inorder to satisfy the water enquirement.

2.6.5 Main and Submain

The mainline is a pipe which delivers water from the pump to the submains and may be either permanent or portable Mains and submains are designed on the basis of both capacity and uniformity . Capacity means the unit size should be large enough to deliver the required amount of water needed to irrigate the field. Uniformity means the unit should be desingned to maintian an allowable pressure variation so that the flow into all lateral lines will have little variation.

Jayakumar <u>et al</u> (1988) suggested that HDPE main pipes of diameter 40 & 50 mm with wall thikness of 2.5 to 3 mm and pressure withstanding capcity of 4 kg/cm^2 can be used for big gardens. The submain is generally a rigid black polyethylene pipe , with diameter varying from 30 mm to 90mm.

2.6.6 Laterals

Laterals receive water from the submains and supply it to the sprinkler head. Commonly used laterals are flexible polythylene or PVC pipes. Wu and Githin (1973) developed a procedure for drip irrigation system for determining lateral pipe size. In 1974 they introduced the design charts for lateral lines based on dimensionless ratio between the minimum and maximum pressures at the end of the lateral tube. PVC pipes having diameter 12-25 mm are frequently used as the micro-sprinkler lateral.

2.6.7 Micro- Sprinklers

Micro-sprinkler and micro-jet emitters are disigned to distribute water in the form of a fine rain-like shower. The primary difference between micro - sprinkler, and micro-jet is that with the former, the water jet rotates while the latter is static.

Recent micro-sprinkler field installtions in the south-east U.S. typically have used 45 to 70 lit/hr emitters and stake assembliss with 0.16 m length of 4 mm spaghetti tubing. Stake assemblies offer several advantages over emitters installed directly in the polyethylene (PE) lateral or installed on risers plugged directly into the lateral. The stake assembly allows the emitter to remain in a fixed position, even if temperature extremes cause movement of one meter or more in the lateral tubing. The stake assembly r emitter 20 to 30 cm above the ground surface, thus allowing water to be discharged above low growing grasses and weeds. The added elevation can also increase the coverage diameter of many emitter models. Performance of the emitters is also enhanced since they stand on a firm base and do not rotate to non vertical position when the lateral tubing moves or twists. The standard industry spaghetti tubing for micro-sprinkler using stake assemblies has 4 mm diameter size.

2.7 Economy.

Compared to other sprinkler systems, the micro-sprinkler systems are economical to install and have low discharge rates. The efficient hydraulic design of the micro-sprinkler, coulpled with the correct use of flow regulators, accounts for the diminishing price difference between drip irrigation and micro-sprinkling systems.

In todays economic conditions, when farm inputs are becoming more and more expensive, the cost of irrigation may be the decisive factor in determining the profitability of a given orchard. The highest economic return is the main objective in this market. The efficiency with which we apply water or fertilizers, or the use of a multi-purpose system that can save labour and materials has to be cosidered when making decisions on irrigation systems.

According to Mane (1986) there is 50 percent economy in irrigation water in micro-irigation . This is due to partial wetting of the soil volume, reduced runoff and controlled deep percolation losses.

2.8 Pulse Irrigation.

Irrigation with low aplication rates has been found desirable for optimal plant - soil - water relationships, in regard to plant response to soil moisture regime and water movement in the soil profile .

Low application rates of the order of 3mm/hr - 5mm/hr are mainly achieved by the use of low discharge sprinklers and also trickle-irrigation systems. However, technical limitations concerning these irrigation devices prevent lower application rates of the order of 1mm/hr and less, sequential or pulse irrigation is suggested. It is based on a series of pulses, where each pulse is composed of the operating and the resting phases. All other irrigation systems function contiuou sly.

Work reviewed by Grable (1966) has shown that there exists a maximum value of equilibrium volumetric water content of the soil, above which oxygen diffussion though the soil is inhibited. Based on a review of available results on the relationship between inifltration capacity and equilibrium volumetric water content for various soil,it is estimated that the application rate needed to wet most soil directly to a water content lower than the maximum value is in the range of 0.5 -2 mm/hr. None of the available water emitters is capable of applying the water at such low application rates unless the water application rate was used to define the pulsed water application regime. Studies showed that the volumetric soil water content distribution and rate of advance of the wetting front in the soil column behaved as if the time averaged water application rate was being applied continously.

Grossi (1974) summarised the research carried out on trickle irrigation . Two systems were analysed,

1. Continuous ordinary trickle irrigation and
2. Intermittent 'sip' irrigation in which large amounts of water are applied over short periods. Research deal with application of these systems and with capillary sub-irrigation of various crops. Manferinato (1974) studied changes in soil moisture profile under simulated rain, applied at various rates under laboratory conditions.

Layston and Me Elgunn (1975) noticed poor second growth of alfalfa on heavy soil. More frequent irrigation of smaller amounts was recommended for adjustments to be made for normal precepitation.

James L.G. and C.L. Larson (1976) used a model with relatively simple and reasonably accurately measured parameter equation to represent infiltration and redistribution of soil water during intermittent water application . Experimental laboratory data were satisfactorily predicted by the model. The model can be used to predict amount of surface and subsurface runoff, the volume of water stored in the soil zone, wetting front and the infiltration rate.

ZurB (1976) concluded that pulsed water applicati principle could be used effectively to control the wetti of soil during the infiltration process. He also develop water application principle inorder to obtain a design fl appliction rate from any water emitter.

Zue B and Salvaldi (1977) induced periodic changes and at various depth and the analogy of the soil wa regime during the infiltration under a pulsed wa application to a wave propagation was formulated experimentally tested. The time changes in 'θ' at a depth soil columns receving water under two pulsating regimes w well represented by a fourier series. The compu amplitudes of the 'θ' time changes ,Cm,Z, were damp exponentially with depth and the computed phase shi ϕm,Z increased linearily with depth as expected by theory. A similar behaviour was observed with experimentally determined amplitudes. Under the higher and Rav however no damping of the amplitude was observed with a soil depth range of 0.5 to 3.5 cm.

Chizhikovi et al (1980) established relationsh between the application rates and a number of parameter experiments on intermittent irrigation over nine seasons

2.8.1 Design of Pulse Irrigation

David Karmeli and Gideon Peri (1974) reported that application of pulsation technique is dependant on factors (1) Design and management of operational irrigati net-works using the pulse irrigation technique and (2) Theorectical and experimental analaysis of water flow and moisture profiles through the soil as a result of pulse irrigation. The correct determination of pulse characterist cs enables the efficient use of this technique.

David Karmeli (1977) examined the basic principles in the design of a pulsating irrigation system. The main factors mentioned were time components of pulse, direction of operation, resting periods of a single pulse and the relationship between these factor and the number of pulses per irrigation.

2.8.2 Advantages of pulse Irrigation

In the vertical columns, using intermittent water application , the advance of the wetting front, the ecumulative infiltration, and the infiltration rate were decreased and behaved as if the time averaged water application rate were being applied continuously. This decrease was also found with the horizontal columns, but to a considerably smaller extent. In effect, this decrease would change the shape of the wetted soil volume in favour of the lateral direction, when using point-source irrigation. The decrease in vertical water movement can also have favourable implications with respect to losses of water and nutrients beneath the root zone. By making use of intermittent water application, it is also possible to use high-discharge emitters while still obtaining low rates of water

I. Levin and F.C. Van Rooyen (1977). It has been found by numerous workers that higher yield and improved plant growth can be obtained by reducing the time intervals between irrigation and by maintaining low soil moisture stress condition (Hagan (1957) ; Slatyer (1957); Rauritz (1967); Rawitz and Hellel (1969) and Assaf, Levin and Bravdq (1975)

Previous workers have shown that by maintaning a low infiltration rate, a lower value for 'field capacity' can be obtained. (Rubin, Steinhaldt, and Reiniger (1964), Zug (1976) A lower 'field capacity' water content naturally implies better aeration in the root zone of the plants.

Anonymous (1973) claimed that 50 percent more harvest in the case of field crops and five fold increase in yield of sunflower and increase of 1200 grapefruits per tree than under conventional irrgation, when pulse irigation of the period of 1 minute at the interval of every 1hr for a duration of 10 hours is adoted.

Busch and Rochestor (1975) found low application rate of 0.13 inches/hr to be superior to 0.7 inches/hr in cotton production and the minimisation of soil crust strength.

Rawlins and Raats (1975) reported that uniform frequent irrigation optimizes root enviornment while drastically reducing water use.

Hence and Beale (1976) field tested the high frequency irrigation conceptwith trickle, furrow and sprinkler system to compare their effectiveness on sandy soils in the humid regions. High frequency trickle automatically controlled with a soil metric potential sensor improved yeild and water use efficiency.

Komayakov and Ageev (1976) observed that the aerosol method of irrigation is which mist sprays of 200 liters/ha were applied 7 to 9 times per day when required, gave yields 6.5. ton per ha compared with 4.4 ton/ha without irrigation. Water use was $40m^3$|ha comapredwith about $500m^3$|ha for other methods to obtian similar yeilds.

Levin and Van Rooyen (1977) found that water movement is the vertical direction is at a faster rate than in the horizontal to vertical water advance. Such a change in ratio implies change in the shape of the wetted volume of soil beneath the point source in favour of the lateral direction when the water is applied in pulses. This effect is especially large in the sandy loam and can be expected to increase even more toward heavier textured soils . In sand a decrease in vertical soil water advance is a further benefit as excess downward movement of water could cause considerable losses of waterand nutrients below the root zones.

In the medium - textured soil the intermittent water application caused a significant decrease in soil moisture content in the transmission zone with both the vertical and horizontal columns. This implies improved aeration when using intermittent water application in heavier textured soils.

Dev Nir (1982) reported that pulse irrigation which provides water only during a certain fraction of the time, (intermittently) enables to keep the soil moisture at a high level of availability (or low water tension) and supplies the water at the right time.

Rajkumar B (1984) found that pulsating irigation given during night time coupled with mulching has been superb in performance from all aspects - moisture conservasion, maintenance of soil quality and enhanced yields - in the case of raddish and maize.

MATERIALS AND METHODS

A study was conducted to evaluate the performance of different micro-sprinkler heads and micro-jets and to develop a pulsating micro-sprinkler system and to test it. Materials used for the study and the methodology adopted for achieving the objectives are discussed in this chapter under the headings, performance evaluation of micro-sprinkler heads and pulsating micro-sprinkler system.

3.1 Performance evaluation of Micro-sprinkler heads.

3.1.1. Location

The performance evaluation of the micro-sprinkler was conducted inside the Soil and Water Conservation Engineering laboratory of KCAET, Tavanur. The place is situated at $10^{o}53'$ 33" North latitude and 76^{o} East longitude.

3.1.2. Experimental Set-up

In this study four micro-sprinkler heads JG,JB,JW and EP (Spinner type of emitters) of nozzle sizes 1.2mm, 0.8mm, 1.5mm and 1.2mm respectively and two micro-jets (Spray type emitters) K.I. and F.T were used. The micro-sprinkler head was mounted on a 16mm stake at height of 200mm above the top surface of the catch cans. The micro-jets were mounted on its own stand at the same height above the catch cans. The micro-jets were connected to the 16mm lateral by a 0.6m long section of 4mm spaghetti tubing and straight connecters of 4mm.

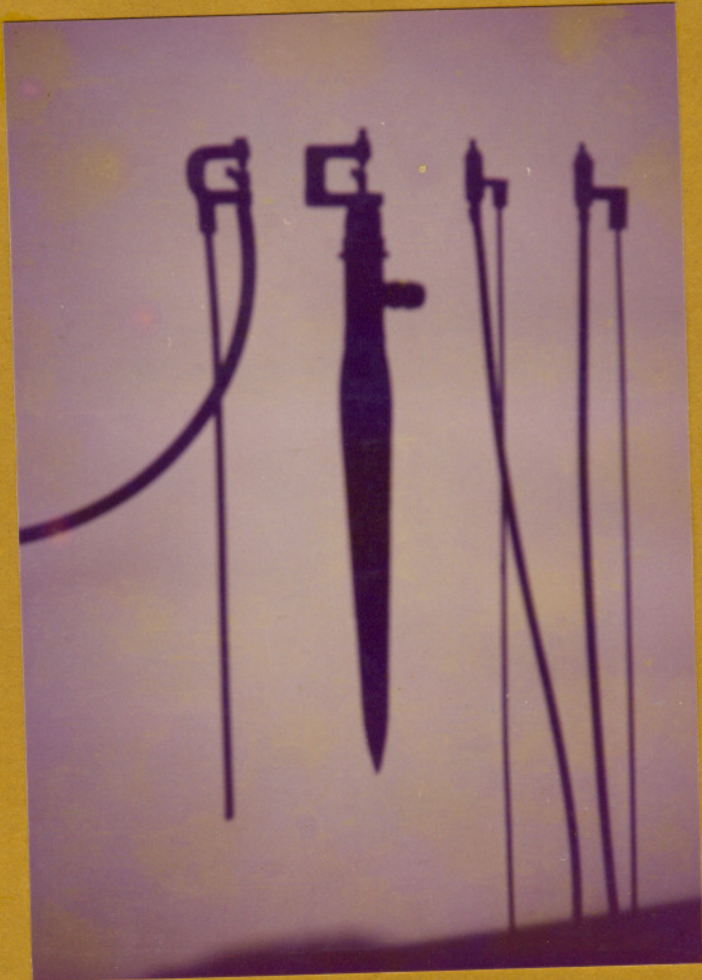


Plate No.1. MICRO-SPRINKLER HEADS.

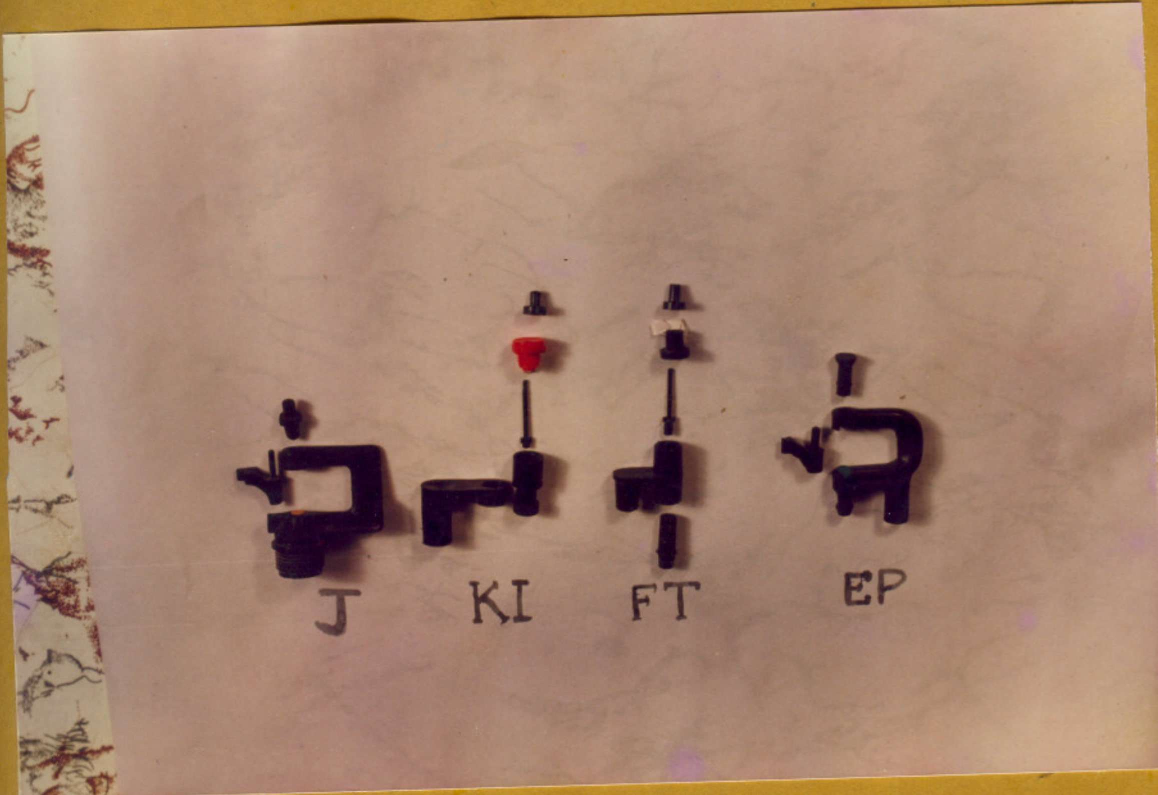


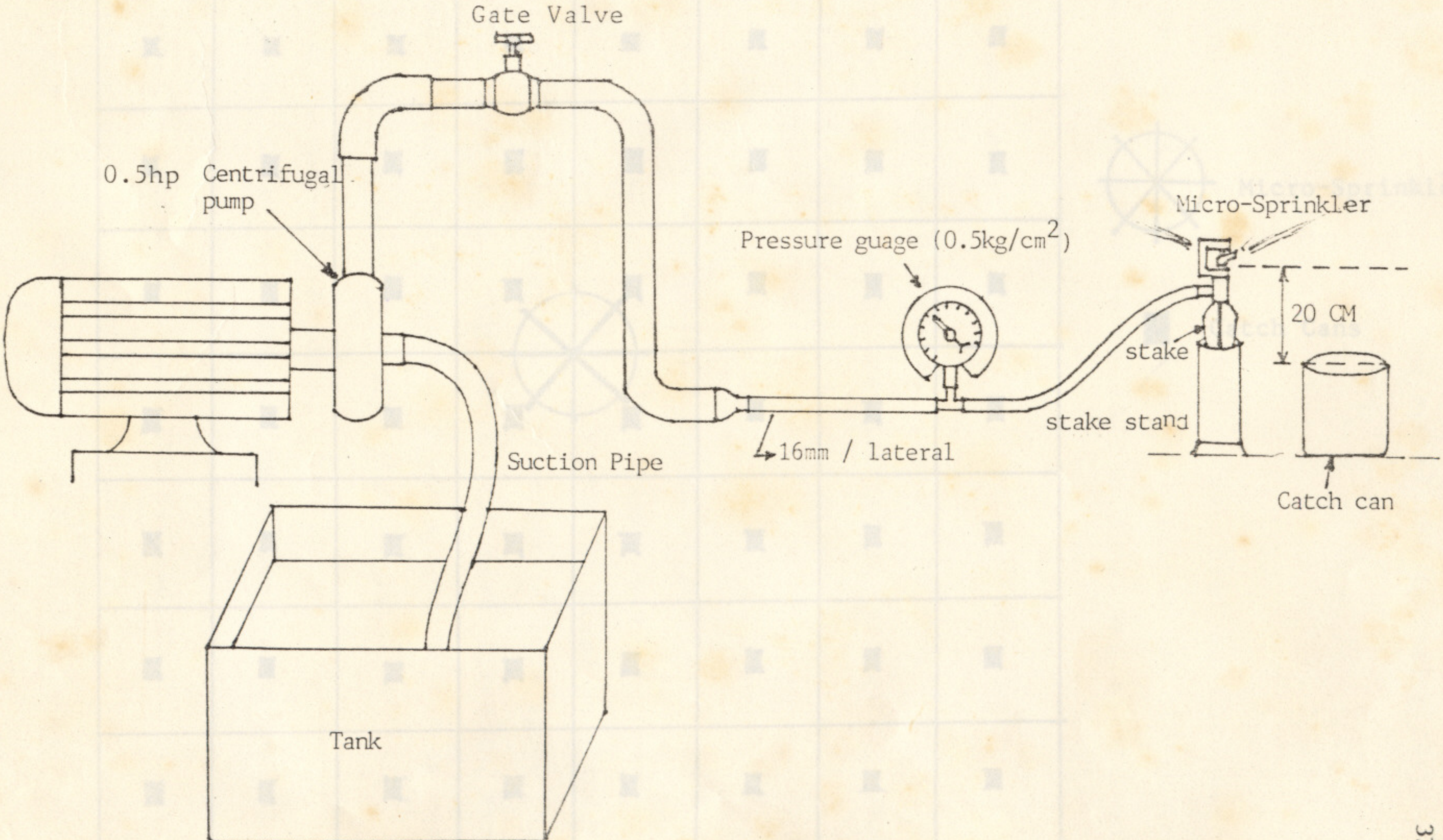
Plate No.2. MICRO-SPRINKLER HEADS - EXPLODED VIEW.

A centrifugal pump operated by an electric motor of 0.5 hp was used to lift the water from the tank and to develop the sufficient pressure. A 40 mesh wire screen was used for filteration of water before collecting in the tank. The discharge line consists of a gate valve attached to a 32mm PVC pipe and a 16mm LLDPE pipe connected to the 32mm PVC pipe. A pressure guage was connected in the 16mm LLDPE pipe close to the stake. The operating pressure was adjusted using the gate valve. The pressure guage was used to indicate the operating pressure. The experiment set-up is shown in Fig. 1.

The operating pressures used in this study were 0.5Kg/Cm^2 (7.11 PSI), 1 Kg/cm^2 (14.23 PSI) and 1.5 Kg/cm^2 (21.34 PSI). The duration of operation for each set of experiment was two hours.

Grids of 60cm x 60cm in an area of 10m x 10m were marked. Catch cans placed at the centre of each square, then represents the precipitation falling on that area. The cans were of 100mm dia. and 120mm ht. The grid covered the entire area of the micro-sprinkler spread.

The testing procedure consisted of setting up a pattern of collectors. The collector placement pattern is shown in Fig. 2. During the operating period, the operating pressure was closely monitored and the pressure was kept constant. The discharge rate of the micro-sprinklers at each pressure was also determined. The testing was done in a closed room


Gate Valve
0.5hp Centrifugal pump
Pressure guage (0.5kg/cm2)
Micro-Sprinkler
20 CM
stake
stake stand
16mm / lateral
Suction Pipe
Catch can
Tank

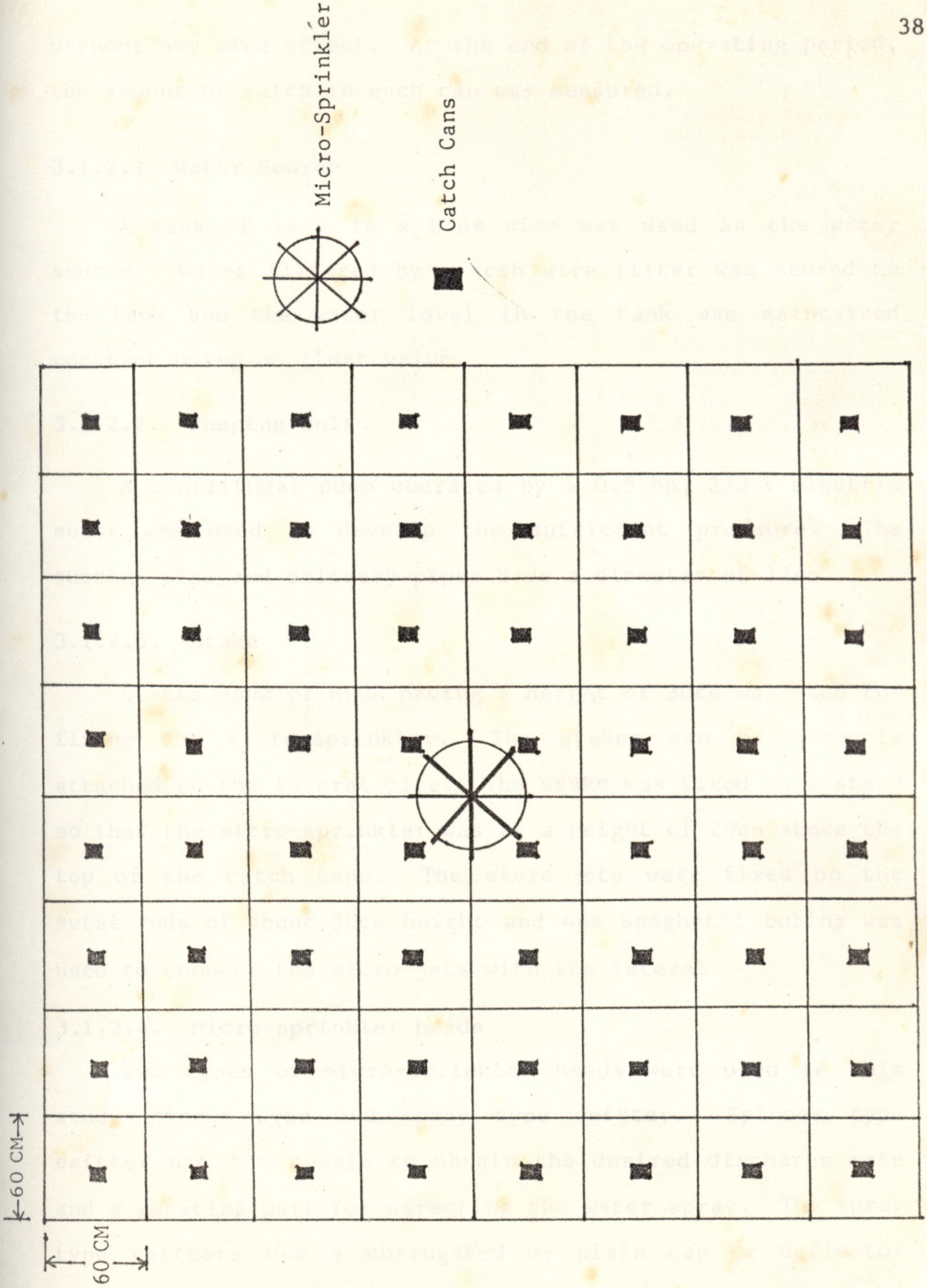


Fig:2 COLLECTOR PLACEMENT PATTERN

without any wind effect. At the end of the operating period, the amount of catch in each can was measured.

3.1.2.1 Water Source

A tank of 1m x 1m x 0.6m size was used as the water source. Water filtered by a mesh wire filter was stored in the tank and the water level in the tank was maintained constant using a float valve.

3.1.2.2. Pumping Unit

A centrifugal pump operated by a 0.5 hp, 230 V electric motor was used to develop the sufficient pressure. The suction pipe and delivery pipes have a diameter of 32mm.

3.1.2.3. Stake

Stakes made of HPDE having a height of 30cm was used for fixing the micro-sprinkler. The stakes can be directly attached to the lateral pipe. The stake was fixed on a stand so that the micro-sprinkler was at a height of 20cm above the top of the catch cans. The micro-jets were fixed on the metal rods of about 30cm height and 4mm spaghetti tubing was used to connect the micro-jets with the lateral.

3.1.2.4. Micro-sprinkler heads

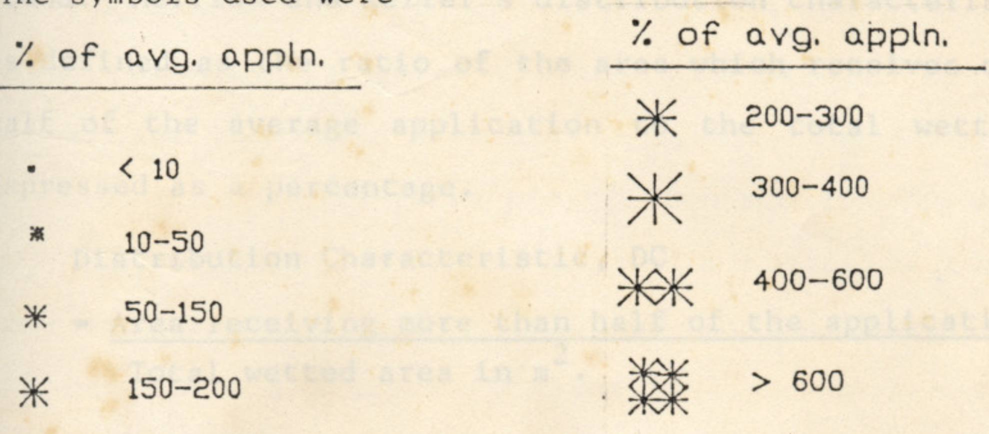
Two types of micro-sprinkler heads were used in this study-spinner type and spray type emitter. Spinner type emitter use the nozzle to obtain the desired discharge rate and a rotating part for directing the water spray. The spray type emitters use a corrugated or plain cap or deflector

Plate No.3. EXPERIMENTAL SETUP.

plate to disperse the water jet. Due to rapid speed of rotation of the spinners, a quick jet break-up is obtained. Spinners emit the water in a jet where as the sprayers emit the water in a number of small streams. For the spinners the deflector is found to be important. In the sprayers, for smooth plates enclosed in a perforated cap, the jet produces a thin film of water on the plate which is then divided into several small streams according to the perforations in the cap. The colour of the nozzle indicate size of the emitters. Four types of spinner emitters JG, JB, JW, EP and two types of spray emitters KI and FT were used in this study.

3.1.3 Determination of Distribution pattern

After operating the micro-sprinkler for two hours duration, the volume of water collected in each can was measured. By dividing the volume with the cross sectional area of the can, depth of application at each grid was obtained. The pattern was drawn which represents the percentage of average application at different distances from the emitters. Different symbols were used to denote different percentages of average application in the pattern. The symbols used were



3.1.4 Determination of Wetted radius

The effective radius (Re) is defined to be the average distance from the emitter to the most distant 5% of containers which receive the water. The effective area (Ae) of applications by the emitter was then calculated as the circular area within a distance of Re from the emitters.

3.1.5 Determination of application depth

The absolute maximum application depth (Dxa) was defined as the greatest depth caught in any of the containers for a particular emitter. The effective maximum application depth (Dxe) was defined to be the average depth caught in the five percent of the containers that had greatest catch depth. The mean application depth (Da) was calculated as the average depth of water caught in the containers located within a distance of Re from the emitter.

3.1.6. Determination of distribution characteristic

The average depth of application of all points within the effective radius of throw was calculated. The area receiving more than half of the average application depth was found. Merriam and Keller's distribution characteristic (DC) is defined as the ratio of the area which receives more than half of the average application to the total wetted area, expressed as a percentage.

Distribution Characteristic, DC

$$= \frac{\text{Area receiving more than half of the application depth in } m^2}{\text{Total wetted area in } m^2}.$$

3.1.7. Determination of Coefficient of Variation

The coefficient of variation (CV) of the catch depth for a particular emitter was calculated by dividing the standard deviation of the depths used to calculate the mean by the mean application depth Da. The CV is expressed as a percentage.

Coefficient of Variation, CV

$$= \frac{\text{Standard Deviation of depth}}{\text{Mean application depth}}$$

Standard deviation of depths used to calculate the mean

$$= \sqrt{\frac{\sum (Di - Da)^2}{N}}$$

Where Di is the individual application depths

Da is the mean application depth

and N is the total number of application depths used to calculate the mean.

3.1.8. Determination of Discharge

A test stand was constructed to hold the stake with the emitter, for the evaluation of discharge. Stakes, with emitters attached, were inserted vertically in the stand. The stake assemblies were connected to the supply system with barbed adapters. A 100mm diameter can was placed over the emitter and the stake assembly to confine the discharge and direct it into the 19 litre plastic container. The discharge was collected in the container for a specified time. The specified pressure was maintained during the test and monitored with a guage in the supply line near the emitters.

Plate No.4. MEASUREMENT OF DISCHARGE.

The time was noted using a stop watch. The volume collected was measured using a measuring jar.

$$\text{Discharge in litres/hr} = \frac{\text{Volume collected in litres}}{\text{Time interval in hours}}$$

Thus the discharge of different emitters at different operating pressures were determined.

3.2 Pulsating Micro-sprinkler system

3.2.1. Location

The pulsating micro-sprinkler irrigation system was installed and tested in a small garden inside the Soil and Water Conservation Engineering Department of KCAET, Tavanur in Malappuram District of Kerala.

3.2.2. Climate

Agroclimatically the area falls between the border line of northern zone, central zone and kole zone. Climatologically the area falls in the rainfall zone (1000 to 2000mm). Medium and high rainfall zones are available, within 10 to 15 km of the area. The area receives the rainfall mainly from South-West monsoon and certain extent from North-East monsoon.

3.2.3. Site Preparation

The selected site of size 15m x 6m was cleared off grasses and bushes and properly levelled. The soil was properly manipulated and farmyard manure was applied.

Plate No.5. WATER SOURCE & PUMPING UNIT.

The pits dug for planting the flowering plants were filled with a mixture of well graded soil, sand and farmyard manure in the ratio 1:1:1 upto a depth of 2cm below the ground level. Planting was done two to three weeks after filling the pits. Garden plants were planted in a suitable pattern during evening hours. Irrigation was done soon after planting.

3.2.4. Irrigation

Pulsating micro-sprinkler irrigation system was adopted for the garden plants. The component parts of the system are described below. The layout of the system is shown in plate.

3.2.4.1. Pump

A centrifugal pump operated by a 0.5 hp 230 V ac electric motor was used to deliver water to the micro-sprinklers at the correct pressure. The suction and the delivery pipe were of 32mm diameter.

3.2.4.2. Storage Tank

A square tank of size 1m x 1m x 0.6m having a capacity of 600 litres was used as the storage tank. The water level in the storage tank was maintained always between 50 to 60cm from the bottom of the tank, using a float valve.

3.2.4.3. Filter

To avoid the entry of bigger suspended inorganic particles, filteration is used on the system. A 40 mesh wire screen was used for filteration of water before supplying it to the storage tank. It consists of the following parts - a

Plate No.6. MICRO-SPRINKLERS - IN OPERATION AT THE SITE.

GI encloser, 40 mesh wire screen and appertunance. The filter was washed and cleaned every week.

3.2.4.4. Main line

A PVC pipe of size 32mm was used as the main supply pipe. A gate valve was connected in the line to control the operating pressure.

3.2.4.5. Laterals

Black LLDPE pipe of size 16mm was used as the lateral and was laid in the field in between two consecutive rows of plants. The laterals were connected to the main using start connectors. The ends of the laterals were plugged using end plugs which can be removed to facilitate flushing. Irrigation of 2 rows of plants using a single lateral is shown in plate.

3.2.4.6. Emitters

Micro-jets or spray type emitters with an application rate of 8.85mm/hr at a pressure of 1 Kg/cm^2 were used as the emitters. The micro-jets were push fitted into the spaghetti tubing of 4mm diameter, which were provided along with the micro-jets. Holes were made on the lateral by a dripper punch and start connectors (Barbed adaptor) were pushed into it. The other end of the spaghetti tubings were push fitted into the start connectors. The emitters were installed in the field by inserting the stakes into the soil to a certain depth, between two rows of plants. Components of the micro-sprinkler system is shown in plate.

3.2.5. Pulsation system

Pulse irrigation is based on a series of pulses, where each pulse is composed of operating and resting phases. Sequential or pulse irrigation is suggested in order to reach lower application rates of the order of 1mm/hr and less. The irrigation rate of the soil in the site ws measured using an infiltrometer and was found to be 12mm/hr. The application rate was adjusted to suit the soil type, the infiltration rate of the soil and plant response to soil moisture regime.

Various innovations are offered to enable pulse irrigation, the main one being the control boards which open and close valves sequently according to a desired design.

The term pulse irrigation is defined as a series of irrigation time cycles, where each cycle includes two phases (1) the operating phase of the irrigation system: and (2) the phase during which the system is at rest. The irrigation in the first phase is carried out with a relatively high precipitation rate: however, when the time of resting phase is taken into account, the average precipitation rate is relatively low. The pulse irrigation pattern is as shown in Fig. 3.

In the figures 3, the following parameters of pulse irrigation are defined.

Tc = the total irrigation time, in hours

V_T = Total amount of water applied, in mm.

I_{sp} = Precipitation rate of the given irrigation device in mm/hr

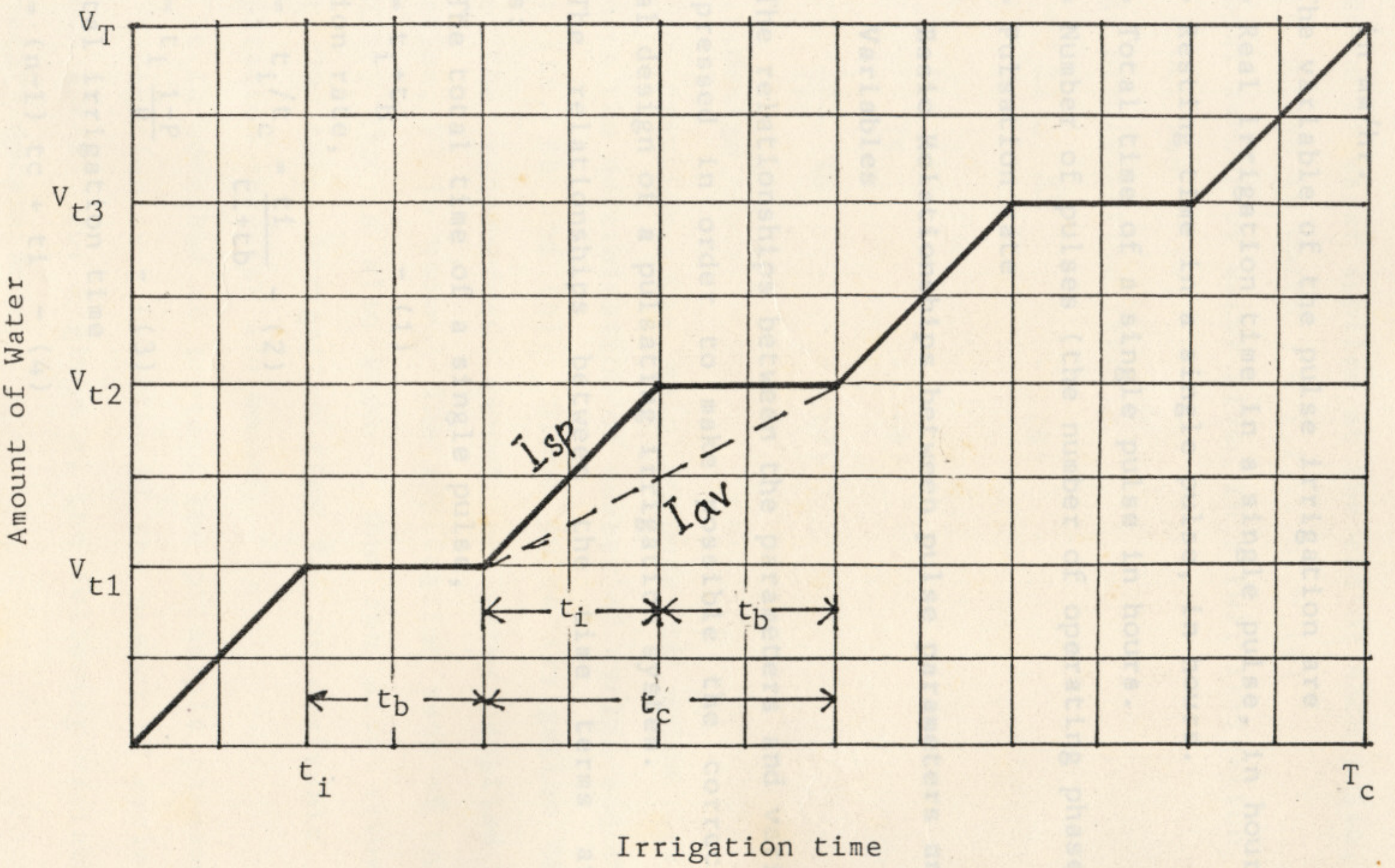


Fig:3 PULSE IRRIGATION PATTERN

V_t = The total amount of water applied during each pulse, in mm.

I_{av} = Average application rate of the given irrigation device in mm/hr.

The variable of the pulse irrigation are

ti = Real irrigation time in a single pulse, in hour.

t_b = Resting time in a single pulse, in hours.

t_c = Total time of a single pulse in hours.

n = Number of pulses (the number of operating phases)

P = Pulsation rate

3.2.5. Basic Relationships between pulse parameters and Variables

The relationships between the parameters and variables are expressed in order to make possible the correct and rational design of a pulsating irrigation system.

The relationships between the time terms are as follows:

The total time of a single pulse,

$$t_c = t_i + t_b \qquad - (1)$$

Pulsation rate,

$$P = t_i / t_c = \frac{ti}{ti+tb} \qquad - (2)$$

$$t_b = t_i \frac{1-P}{P} \qquad - (3)$$

The total irrigation time

$$T_c = (n-1)\ tc + ti \qquad - (4)$$

$T_c = nti + (n-1)\ tb = n\ (ti+tb) - tb$ - (5)

Relationships between water quantities and precipitation rate are as follows:

The amount of water applied at the end of each pulse,

$Vt = jtiIsp$ in which $j = 1,2,...n$. - (6)

The total amount of water given in a full irrigation,

$V_T = nti\ Isp$ - (7)

Average precipitation rate,

$$Iav = \frac{VT}{Tc} = \frac{Vt}{ti} \quad - (8)$$

$$Iav = \frac{nti\ Isp}{Tc} \quad - (9)$$

$$nti = \frac{Iav}{Isp}\ Tc \quad - (10)$$

3.2.5.2. Design

In practice, the main purpose of pulse irrigation design is the determination of number of cycles and the time terms. (ti, tb and tc). Since pulse irrigation does not change the recommended amount of water applied in an irrigation, VT is known. The application rate of the micro sprinkler, Isp is also known. One can also assume that either the total irrigation time Tc, or desirable average precipitation rate Iav are known.

It is possible to express the principle parameters of pulse irrigation as a function of the number of cycles, n ..

In such a case, for a given n, the following variables can be directly determined.

We define for simplicity, $R = \frac{Iav}{Isp}$

The pulsation rate, $P = \frac{R(n-1)}{n-R}$

The real irrigation time in a cycle, $ti = \frac{R(n-1)Tc}{n^2-n}$

The resting time, $tb = \frac{Tcn\ (1-R)}{n^2-n}$

As n increases, the assumption of the average application rate becomes more accurate. On the other hand technical considerations make clear that a small n is desirable. Then a criterian for choosing the proper n is suggested.

This criterian involves the ratio ti/tb. This ratio is a function of n and is expressed as 'y'.

From the curve in Fig. 4, a qualitative definition of n can be made based on the following principle. The variable n can be increased in the steep zone of the curve, so that a relatively small change of n will be followed by a relatively large change in 'y'. It is not efficient to increase 'n' while the change in 'y' caused by this increment is small. So from the figure 4 it can be recommended that the range of n be 8 to 10.

3.2.5.2.1. Relationships between pulses, number of stations and sets

For pulsating system to be efficient, it is desirable that the design be based on operational sets consisting of a number of stations. A station is a valve or a group of

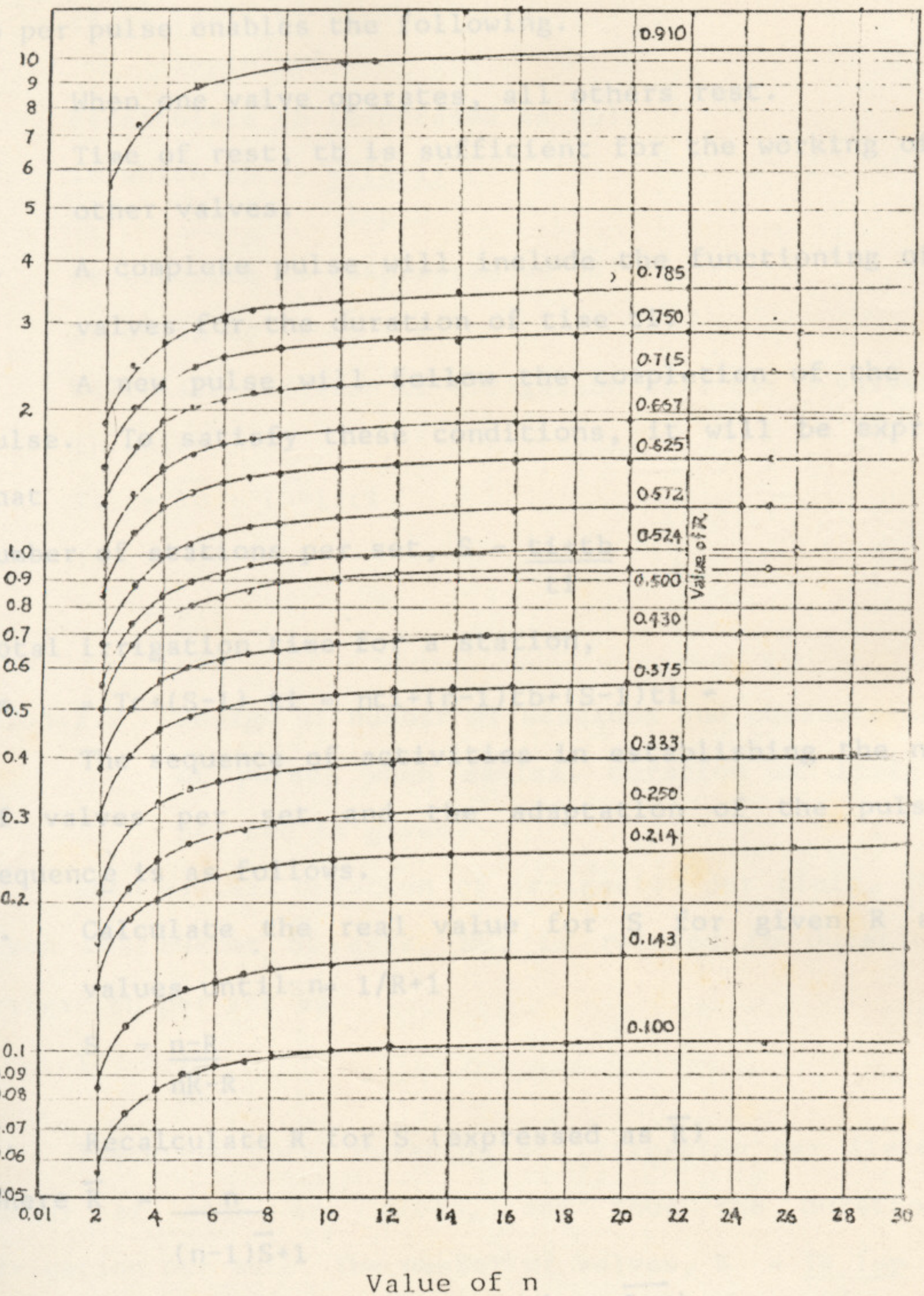


Fig.4 Ratio t_i/t_b as function of number of cycles n for given values of R.

valves working and resting simultaneously. A pulsating system is efficient when time of application, ti and rest, tb per pulse enables the following.

1. When one valve operates, all others rest.
2. Time of rest, tb is sufficient for the working of all other valves.
3. A complete pulse will include the functioning of all valves for the duration of time ti.

A new pulse will follow the completion of the first pulse. To satisfy these conditions, it will be expressed that

number of stations per set, $S = \frac{ti+tb}{ti}$

Total irrigation time for a station,

$Ts = Tc+(S-1)\,ti = nti+(n-1)tb+(S-1)ti$

The sequence of activities in establishing the number of valves per set and the adaptation of the pulsating sequence is as follows.

1. Calculate the real value for S for given R and n values until n= 1/R+1

   $S = \frac{n-R}{nR-R}$

2. Recalculate R for S (expressed as $\overline{R}$)

Where $\overline{R} = \frac{n}{(n-1)\overline{S}+1}$

3. Recalculate Iav (expressed as $\overline{Iav}$)

   in which $\overline{Iav} = Isp\,\overline{R}$

4. Recalculate Tc (expressed as $\overline{Tc}$)

   in which $\overline{Tc} = \frac{VT}{\overline{Iav}}$

5. The value of ti is not a variable, because it depends upon the constant factors VT and Isp.

$$ti = \frac{(n-1)\,VT}{Isp(n^2-n)}$$

6. Recalculate tb (expressed as $\overline{tb}$)

in which $\overline{tb} = \frac{VT(\bar{S}-1)}{Isp.n}$

7. Recalculate tc (expressed as $\overline{tc}$)

in which $\overline{tc} = \overline{tb} + ti$

8. Calculate duration of irrigation (Ts) for S valves, in which

$$Ts = \overline{Tc} + (\bar{S}-1)ti$$

$$Ts = \overline{Tc} + tb$$

$$= \frac{VT\bar{S}}{Isp}$$

3.2.5.2.2 **Design of number of stations and characteristics of pulses when maximal duration of irrigation per set is given.**

When maximal duration of irrigation per field, TN, is given the number of sets, NS, is related to duration of irrigation per set as

$$Ts = \frac{TN}{NS}$$

Therefore total duration of irrigation per field and number of sets are given, and thus the duration of irrigation per set. The number of valves, $S = \frac{Ts\ Isp}{VT}$

3.2.5.2.3. Design of Sets and Number of stations where total duration of irrigation and number of stations are given

The total number of valves, $Nv = \frac{Tn\ Isp}{VT}$

The design of pulsating system (Where Nv greater than or equal to $\frac{TN\ Isp}{VT}$

1. The number of sets Ns and number of stations S such that the following constrains will be simultaneously satisfied.

   a) $Nv < \frac{Ns}{S}$

   b) $\frac{2-R}{2R-R} \leqslant S \leqslant 1/R$

   c) S and Ns are presented in discrete values:

   and

   d) $Nv - \frac{Ns}{S} < S$

2. The remaining number of stations according to

   $\overline{SR} = Nv - \frac{Ns}{S}$

   in which $\overline{SR}$ represents the remaining stations operating as a single set and different from the other sets.

3. The pulse irrigation sequence for each set up with S stations.

4. The duration of time for irrigation of a set by

   Ts = TR = Tn-(Ns x Ts)

   Where TR = remaining time for the remaining set.

5. The application rate for the remaining set of valves by $VT = TR\ Isp \sqrt{SR}$

6. The value of R for the remaining stations as a function of n.

$$R = \frac{n}{n+(\overline{SR}-1)(n-1)}$$

7. The value of Iav for the remaining stations according to Iav = Isp x R.

8. The total duration of irrigation per single station

$$Tc = \frac{(n^2-n)}{n^2-nR} TR$$

9. The real duration of an actual single pulse operation,

$$ti = \frac{R(n-1)tc}{n^2-n}$$

10. The duration of resting period for a single pulse,

$$tb = (\overline{SR}-1)ti$$

11. Total length of time for a single pulse, ti from

$$tc = ti + tb$$

3.2.6. Control Board

The control board consists of an electronic timer with on and off delay adjustments. The on-delay of the timer can be varied from 0 to 40 minutes. With a slight modifications in the circuit, the on-delay can be varied from 0 to 8 hours or more. The off-delay can be varied from 0 to 30 minutes. The off-delay also can be varied by slightly modifying the circuit. The timer circuit has two controls by which the on-delay and off-delay can be adjusted to suit the pulsation rate. The on-delay and off-delay are suitably adjusted so that the application rate is 1mm per hour.

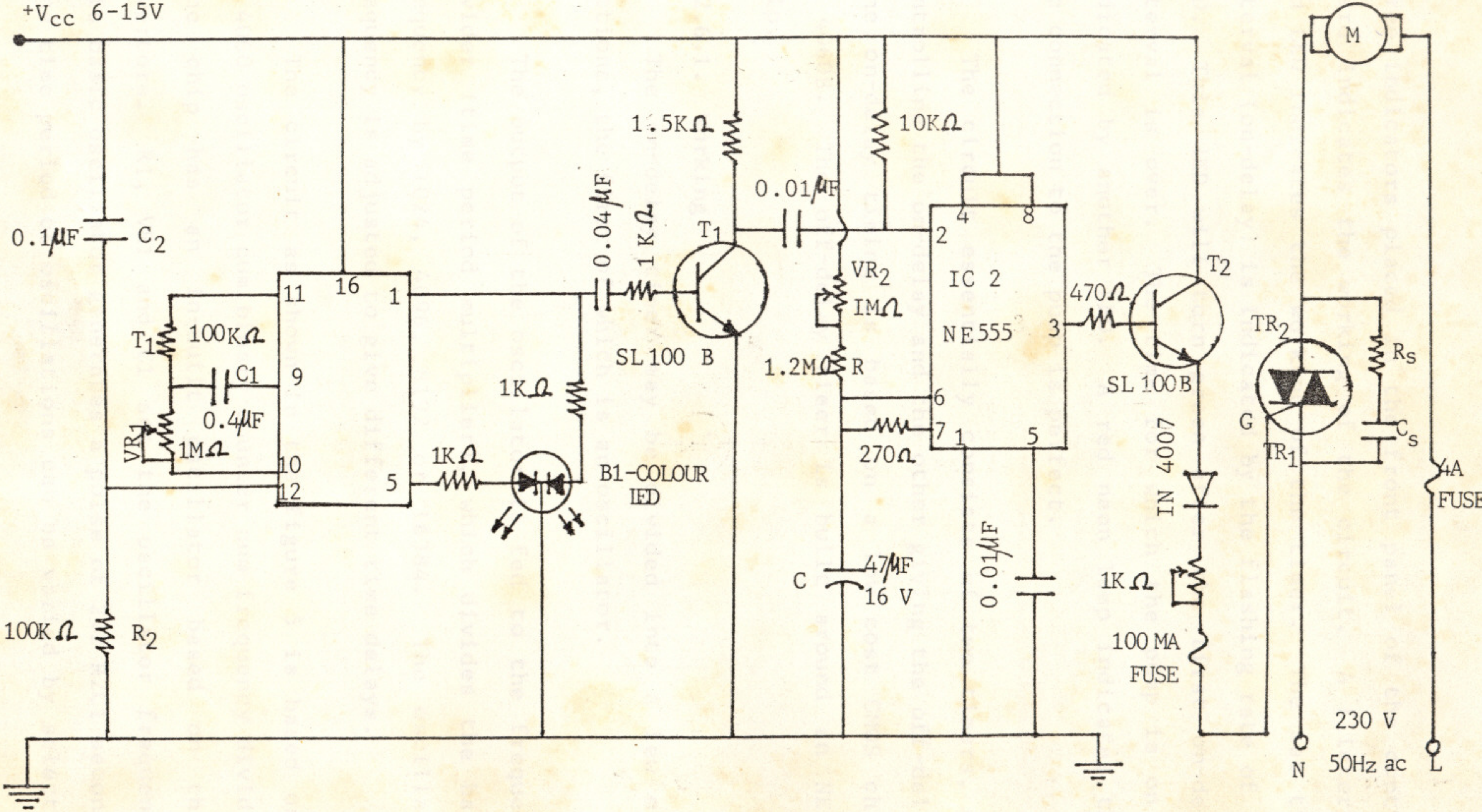


Fig:5 CIRCUIT DIAGRAM OF THE ON-OFF TIMER

Three indicators placed in the front panel of the control board indicates the working of the circuit. A flickering red LED indicates the working of the timer. The set time interval (on-delay) is indicated by the flashing rate of the LED. This LED will turn green after the first on-delay interval is over. The time for which the pump is on is indicated by another LED. A red neon lamp indicates that the connection to the pump is perfect.

The circuit essentially consists of two timers, one controlling the on-delay and the other giving the off-delay. The on-delay timing is based on a low cost CMOS chip, CD 4060B. The off-delay timer is built around an NE555 chip.

3.2.6.1. Working

The on-delay timer may be divided into a few main sections, the first of which is an oscillator.

The output of the oscillator is fed to the frequency divider (time period multiplier), which divides the basic frequency by 1024, 4096, 8192 or 16384. The oscillator frequency is adjusted to give different time delays.

The circuit as shown in the figure 5 is based on a CD 4060 oscillator cum binary counter cum frequency divider. The chip has an in-built oscillator based on three invertors. R1, VR1 and C1 set the oscillator frequency. This basic oscillator generates a pulse of 2.2 R2C1 seconds. The time period of oscillations can be varied by selecting

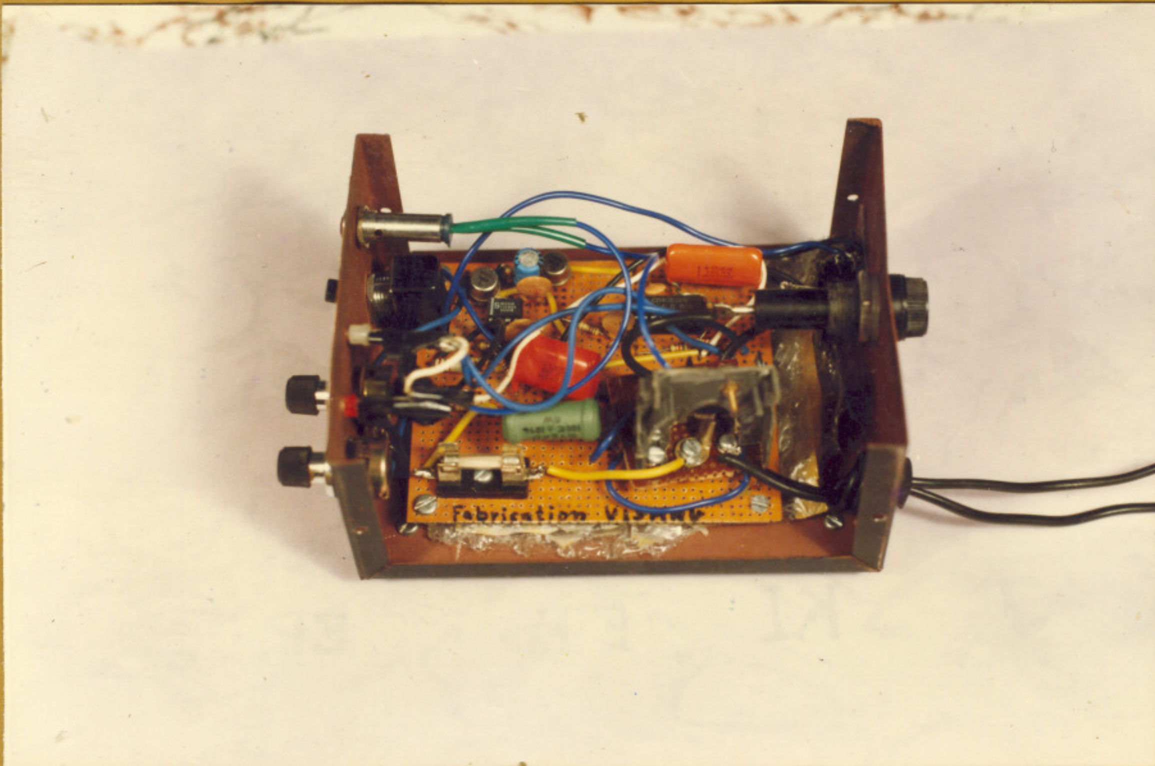


Plate No.7. TIMER - INSIDE VIEW.

suitable R2 and C1. This time period is fed to the counters, and the division factor can be selected from the different pins of the chip.

The circuit can operate in the voltage range from 3 to 15 volts. In the pin diagram of the IC CD4060B is given in the Appendix 2.

Q4 denotes the clock frequency divided by 2^4, Q7 that by 2^7 and so on.

The off-delay timer consists of an IC NE555 which has an oscillator and a RS flip flop. The IC is wired in the monoshot or monostable mode. The time period is given by, W = 1.1 RC.

The time period can be varied by adjusting the values of R and C

After the set time period is over, Pin 1 of the IC CD4060 goes high. This pin is connected to the base of transistor T_1. When the pin goes high, the transistor conducts and a triggering pulse is applied at the pin of the IC NE555 go high. This turns on the transistor t_2. The pin remains high for the time period set by VR_2. After that the transistor T_2 goes off. The transistor T_2 is connected to a gate of the triac. When the transistor is on sufficient gate current passes through the trial and it conducts, thus the pump is turned on. After the set off-delay time is over the pin of IC 555 goes low and transistor T_2 goes off. This will stop the gate current through the triac and the triac stops conducting. This makes the pump off. The triac used has a rating of 400V, 6 A. A snubber circuit is provided across the terminals TR_1 and TR_2 of the triac. So that it is protected from surge voltages.

A regulated power supply of V dc, 500 mA is used as the power source for the timer circuit.

3.2.6.2. Construction

The complete timer circuit was assembled on a general purpose PCB. The construction has been started by soldering the resistors followed by the capacitors and the LED's, diodes and IC sockets. A suitable heat-sink is provided for the triac. Heat-sink compound was applied while fixing the heat-sink. The circuit was housed in a small cabinet. The flashing of the LED makes sure that the circuit is working properly.

3.2.7. Micro-Irrigation design aspects.

Effective performance of a proposed irrigation system depends on its efficient design, layout and management. The design and operation of micro-irrigation system must integrate the plant, soil and the system parameters. Micro-irrigation uses a pressurized pipe network with an operating pressure of upto 2 KG/cm^2 and low rate of application. The network consists of spaghetti tubing, laterals, submains and main lines. The laterals are designed to distribute irrigation water throughout the field with an acceptable degree of uniformity. The submain delivers water to the laterals and also need adequate design to achieve uniform flow to the laterals. The main line serves as a conveyance system for delivering the total amount of water at the required pressure to the irrigation system.

3.2.7.1. Emitter Selection

Micro-irrigation emitters consists of drippers, spray emitters and spinner emitters. The emitters are selected according to the amount of plant rootzone desired to be wetted and the application rate desired. Selection of emitters should be made in conjunction with comparable piping and filteration system. Normally one third to as much as three fourths of the plant cooling volume should be supplied with water in the case of drippers and whole the rooting volume is wetted in the case of micro-sprinklers. Normally emitters are located near the plant or the area of high root concentration.

3.2.7.2. Lateral line design

Flow in the lateral line and submains are hydraulically studied. In designing laterals due consideration is given to the emitter flow variation so that it is within acceptable limits. When emitter and emitter spacing are selected based on the crop requirement and soil conditions, the total discharge at the inlet section for a given length under an operating pressure can be determined. Knowing the total length and operating head, L/H ratio is calculated. From the known discharge, slope and L/H ratio suitable size for lateral pipe can be obtained from design charts for both uniform and non-uniform slopes. Knowing the length and discharge the friction loss can be computed using the Darcy Weisbach's equation as,

$$Hf = \frac{4flv^2}{2gd}$$

Where Hf = Head loss in meters

f = friction factor

l = length of pipe in meters

v = Velocity of fluid in metres per second

g = acceleration due to gravity in metre per S^2

d = diameter of the pipe in metres

3.2.7.3. Submain design

The design of submain is based on both capacity and uniformity. Capacity means the submain size should be large enough to deliver the required amount of water to irrigate the field. Uniformity means the submain should be sufficient to maintain an allowable pressure variation so that the flow into all lateral lines will have little variation. Knowing the discharge requirement of a lateral and the number of laterals in a submain the discharge requirement of a submain can be computed. Knowing the discharge and slope, the suitable size of submain pipe is selected from design chart. The friction loss can be computed by the Darcy Weisbach's equation a described above, knowing the length and diameter of the submain.

3.2.7.4. Main line design

The main line is designed to supply the required discharge of a specified operating pressure into each field for micro-sprinkler irrigation. It should be designed in such a way that the total energy at any outlet along the mainline is equal to or greater than the energy required for operating the entire system. Then the design approach is mainly to determine the allowable energy drop for all maintain section. The main pipes should be selected to minimise the operating cost over the lifetime of the main pipeline. The total cost of the micro-irrigation system can be obtained knowing the cost of individual pipes, fitting and accessories.

3.2.7.5. Pump Selection

Pumps are chosen to match the required performance characteristics of the irrigation system at a high level of efficiency. The first step is to develop an irrigation system performance curve which relates the total system head to discharge. The total system head is divided into two components: the fixed head and the variable head. The fixed head does not vary with discharge. It is made up of difference between the static waterlevel and elevation to the discharge point. The variable system head increases with increase in discharge. It is made up of well draw down if the water source is a well, the friction loss in pipe line and fittings, pressure at the outlet, plus velocity head. The sum of the fixed and variable system operating heads is the total dynamic head.

For a particular pump, manufactures produce pump performance curves which graphically relate the head-discharge relation, pump efficiency, and shaft input requirements of the pump-system performance curves are applied in conjunction with pump performance curve. A pump in good working order always operates on its own performance curve. The affinity loss constrain the pump from moving off that curve. The system performance curve indicates the range of values over which the system may operate. There is only one point on the system performance curve which intersects the pump performance curve. Since the pump is contrained to operate on its curve, it will produce the head and discharge indicated for the intersection of the system and pump curves. The performance curve for the pump chosen must be inspected to check that the pump is able to operate at a high level of efficiency relative to the design requirements of the irrigation system. This will ensure a cost effective operation over the life of the system.

3.2.8. Testing of the System

The infiltration rate of the soil at the site was measured using an infiltrometer. The application rate of the irrigation system was selected to match the infiltration rate of soil, Soil-plant-water relations and to give a good areation. An application rate of less than 1mm/hr is found to desirable for the type of soil and for good areation.

The on and off time of the pulse was selected to give application rate 1mm/hr.

$$\text{The avarage application rate } I_{av} = \frac{I_{sp}.t_i}{(t_i+t_b)}$$

Where Isp is the application rate of the emitter is mm/hr

ti is the on time in hours.

and tb is the off time in hours.

Evapotranspiration rate was determined for different months during which the test was done. The daily water requirement of the plants were considered in relation to the ET allowing sufficient margin for evaporation rates. The on and off time of the pulsating system was found out in relation to the total irrigation time, total depth of water applied in a day and the desired application rate. The on and off time were varied for different months depending on the variation of ET.

Pulsation makes the micro-sprinkler irrigation a high frequency, low depth irrigation system. The duration between wetting cycles were reduced so that the plant stress is decreased. The emitted water distributes to a lesser extent in the vertical plane than in the horizontal direction so that deeppercolation does not occur. The soil is irrigated to a lower "field capacity" so that a good areation is obtained. Once the irrigation is stopped moisture redistribution occur until the potential equalizes at all points.

RESULTS AND DISCUSSION

The results obtained from the experiments to evaluate the microsprinkler performance and to design and develop a pulsating microsprinkler irrigation system are discussed in this chapter. The results of the experiments are discussed under the following captions.

a. Performance evaluation of microsprinklers and
b. Design and development of a pulsating Micro-sprinkler irrigation system.

4.1. Performance evaluation of micro-sprinklers

The performance of four micro-sprinkler heads and two micro jets available in the market were evaluated to determine their moisture distribution pattern, wetted diameter, distribution characteristic and coefficient of variation at different operating presures.

4.1.1. Radius of throw

Several of the spray emitter models had spoke patterns with a few streams putting minor amounts of water well beyond the main area of water application. So a term was designated which appropriately described the wetted area. This was accomplished by defining the term 'effective radius'(Re) to be the average distance from the emitter to the most distant 5% of the containers which received water. The 'effective area' (Ae) of water application by the emitter was then calculated as the circular area within a distance of Re from the emitter. The Re's ranged from 1.7

Table-1 Performance of Micro-spinklers

Micro-spinkler	Pressure kg/cm^2	Discharge lph	Wetted dia m	Mean application rate (Da) mm/hr.	Dxe:Dxa
JB	0.5	22.61	4.06	1.75	2.13
	1.0	32.40	5.52	1.21	4.16
	1.5	42.47	6.20	1.24	4.94
JW	0.5	27.04	5.16	1.10	6.79
	1.0	38.13	6.64	0.94	6.62
	1.5	47.10	6.96	1.03	4.59
JG	0.5	49.85	3.40	2.72	5.25
	1.0	69.51	5.10	1.70	3.74
	1.5	84.58	5.84	1.77	6.03
EP	0.5	29.14	3.40	2.72	4.21
	1.0	41.50	5.10	1.70	2.96
	1.5	52.30	5.84	1.77	3.19
KI	0.5	47.08	1.70	8.14	4.29
	1.0	66.14	2.68	8.85	5.08
	1.5	82.01	4.94	5.22	5.43
FT	0.5	23.37	2.68	1.78	9.40
	1.0	32.99	2.68	5.13	3.53
	1.5	39.72	4.32	2.47	3.17

to 4.24m for the spinner type emitters tested. The corresponding Ae's ranged from 9.1 to 56.5m^2. For sprayer-type emitters Re's ranged from 0.85 to 2.47m. The corresponding Ae's were 2.3 to 19.2m^2.

4.1.2. Application Depth

A problem similar to the radius definition arose with the application depths. Several tests had one or two containers which received water significantly more than any other containers. In this case, two terms were defined. The absolute maximum depth (DX_a) was defined as the greatest depth caught in any of the containers for a particular emitter. The effective maximum application depth (DX_e) was defined as the average depth caught in the 5% of the containers that had greatest catch depths. The mean application depth (D_a) was calculated as the average depth of water caught in the containers located within a distance of R_e from the emitter.

The minimum application depth varied from 0.942 to 2.72mm/hr for spinner type emitters and 1.78 to 8.85mm/hr for spray type emitters. In general, the mean application depths decreased with increase in pressure for both spinner and spray type emitters. In the case of spray type emitters, the application rates were higher at 1kg/cm^2 pressure than at 1.5kg/cm^2. The wetted diameter and application depths of different microsprinklers for pressures of 0.5, 1 & 1.5kg/cm^2 are shown in Table-1.

Table-2 Uniformity Parameter of Micro-Sprinklers

Micro-Sprinkler	Pressure kg/cm^2	Distribution characteristic (DC) %	Coefficient of Variation (CV) %
JB	0.5	53.38	75.19
	1.0	57.17	120.02
	1.5	52.47	130.09
JW	0.5	51.65	151.26
	1.0	46.78	148.35
	1.5	49.30	147.71
JG	0.5	76.50	131.08
	1.0	56.64	105.26
	1.5	53.54	126.02
EP	0.5	67.60	92.59
	1.0	66.96	82.13
	1.5	69.90	77.74
KI	0.5	47.80	138.89
	1.0	51.06	145.05
	1.5	34.38	205.21
FT	0.5	26.00	263.16
	1.0	70.20	96.34
	1.5	94.13	114.44

4.1.3. Distribution Pattern

The moisture distribution pattern for different micro-sprinkler heads under different operating pressures were determined. The percentage of average application depth collected in the cans placed within a distance of R_e from the emitter were calculated. A graph is plotted showing the percentage of average application depths at different distances from the emitter. Different symbols were used to represent different ranges of percentage of average application depth. When the distribution patterns of different micro-sprinklers are analysed, we can see that most of the area received less than 150% of average application.

The distribution patterns of various spinner and spray emitters are shown in figures 6 to 23. The percentages of total area which received different percentages of average application for different micro-sprinklers for operating pressures of 0.5, 1 and $1.5 kg/cm^2$ are given in Table 3.

The spinner emitters applied more than half of the average application of water, to about 33% of the total wetted area. Spray emitters had an average area of about 15% receiving water application near the average value. Spinner emitters had about 26% of the area receiving less

Table-3 Distribution of Water within the wetted area (expressed as percentage of total area)

Micro-sprinkler /	Operating pressure	Percentage of average application							
		<10	10-50	50-150	150-200	200-300	300-400	400-600	>600
JB	0.5	16.7	27.7	30.6	16.7	8.3	-	-	-
	1.0	30.6	16.7	25.0	8.3	8.3	8.3	8.3	2.8
	1.5	26.1	23.9	27.3	6.5	9.1	5.5	3.4	1.1
JW	0.5	43.3	6.7	26.7	8.3	6.7	3.3	3.3	1.7
	1.0	36.5	16.7	22.9	6.3	6.3	7.3	2.1	2.1
	1.5	27.0	21.0	35.0	1.0	8.0	2.0	3.0	3.0
JG	0.5	35.0	18.8	18.8	8.8	11.3	7.5	-	-
	1.0	30.0	10.8	30.0	8.3	15.8	4.2	0.8	-
	1.5	33.8	13.8	27.5	5.6	8.8	8.1	2.5	-
EP	0.5	16.7	12.5	54.2	8.3	4.2	-	4.2	-
	1.0	16.7	20.0	36.7	18.3	6.7	1.7	-	-
	1.5	5.9	17.7	58.8	5.9	8.8	2.9	-	-
KI	0.5	50.0	12.5	12.5	12.5	-	-	12.5	-
	1.0	45.0	15.0	15.0	-	10.0	10.0	5.0	-
	1.5	56.8	11.4	9.1	4.5	6.8	4.5	4.5	2.3
FT	0.5	70.0	10.0	10.0	-	-	-	-	10.0
	1.0	35.0	10.0	20.0	20.0	20.0	-	5.0	-
	1.5	27.3	20.5	22.7	11.4	9.1	6.8	2.3	-

Distribution pattern of JB at 0.5 Kg/cm²

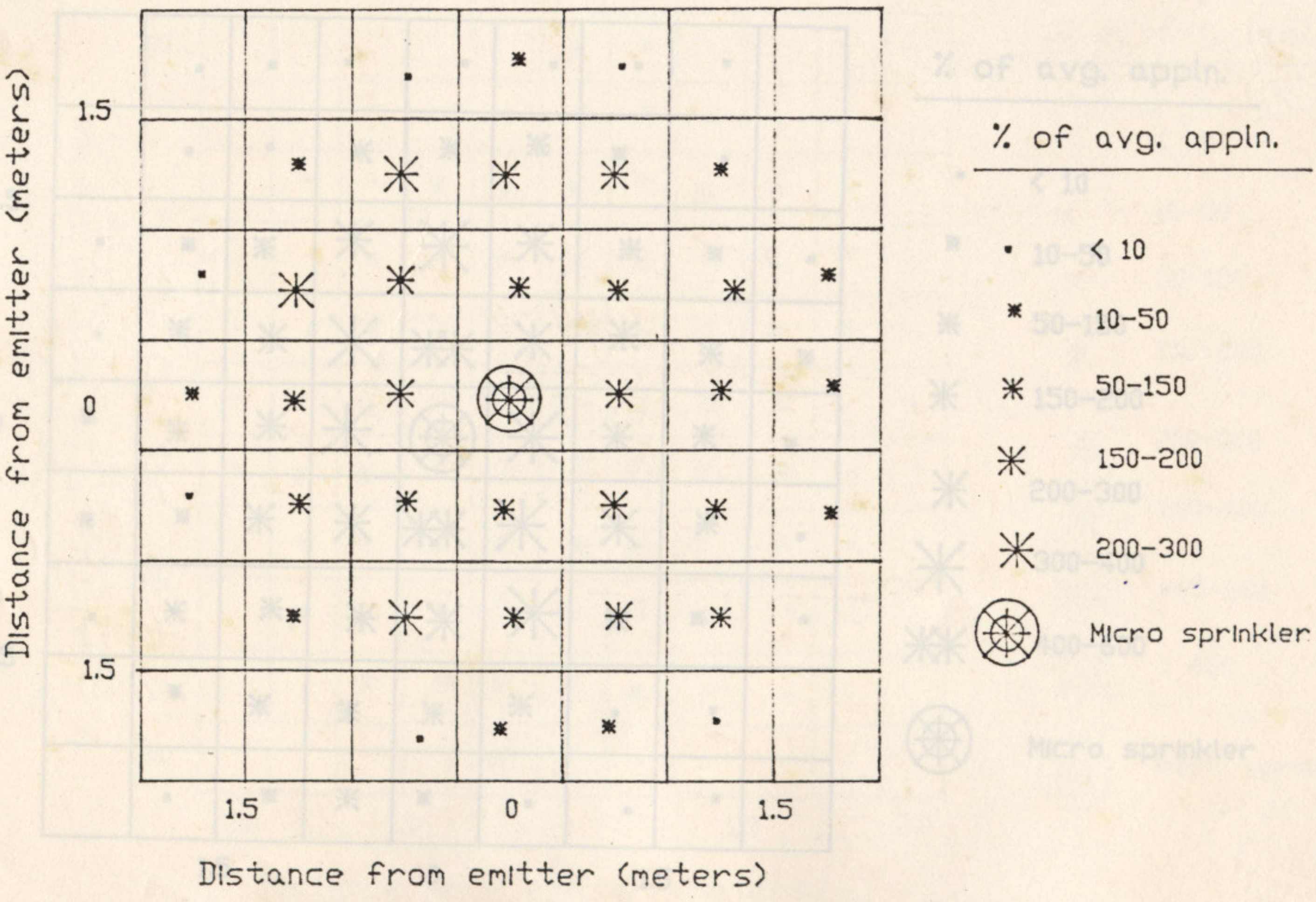


Fig: 6 DISTRIBUTION PATTERN OF JB AT 0.5 Kg/cm^2

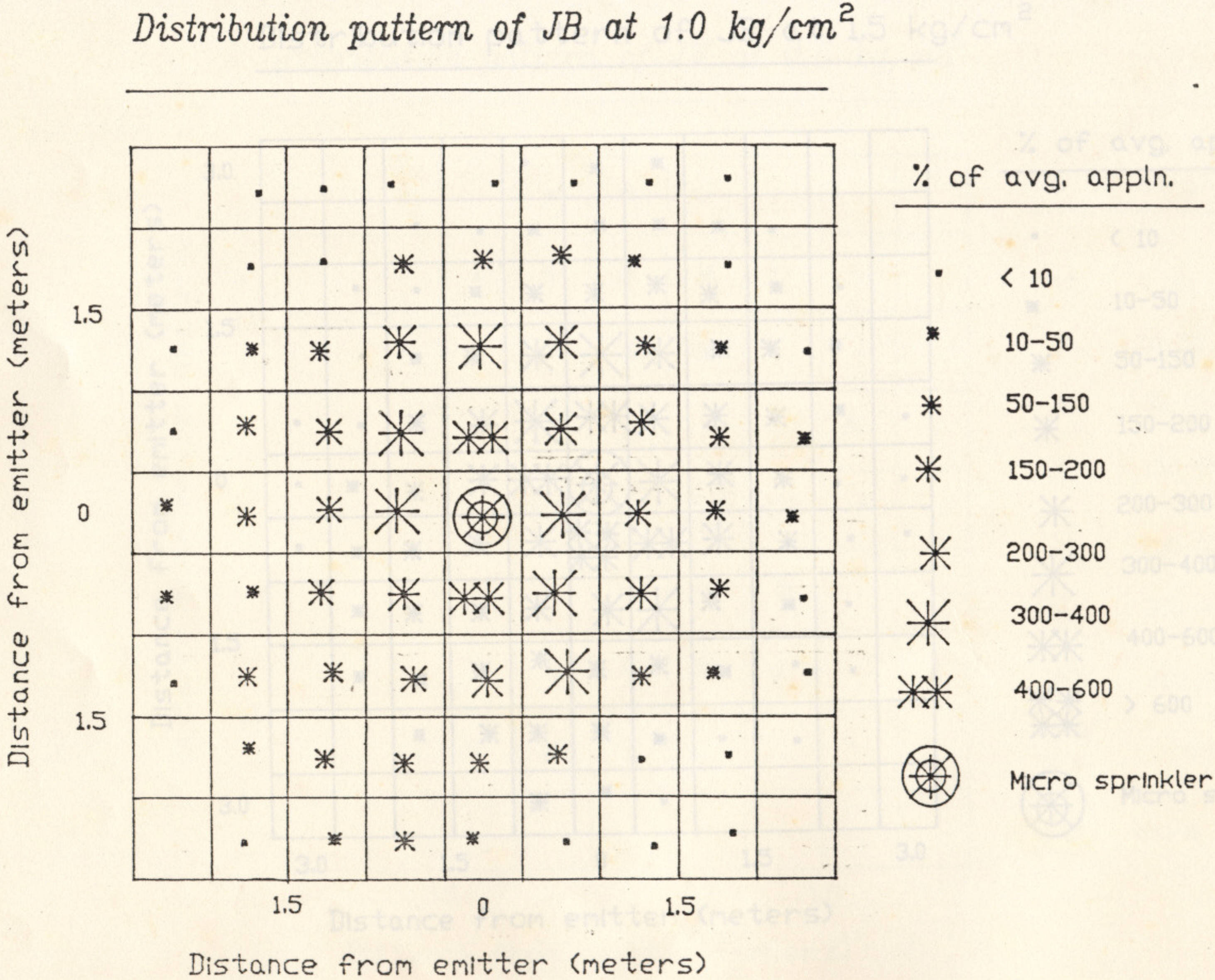


Fig: 7 DISTRIBUTION PATTERN OF JB AT 1.0 Kg/cm^2

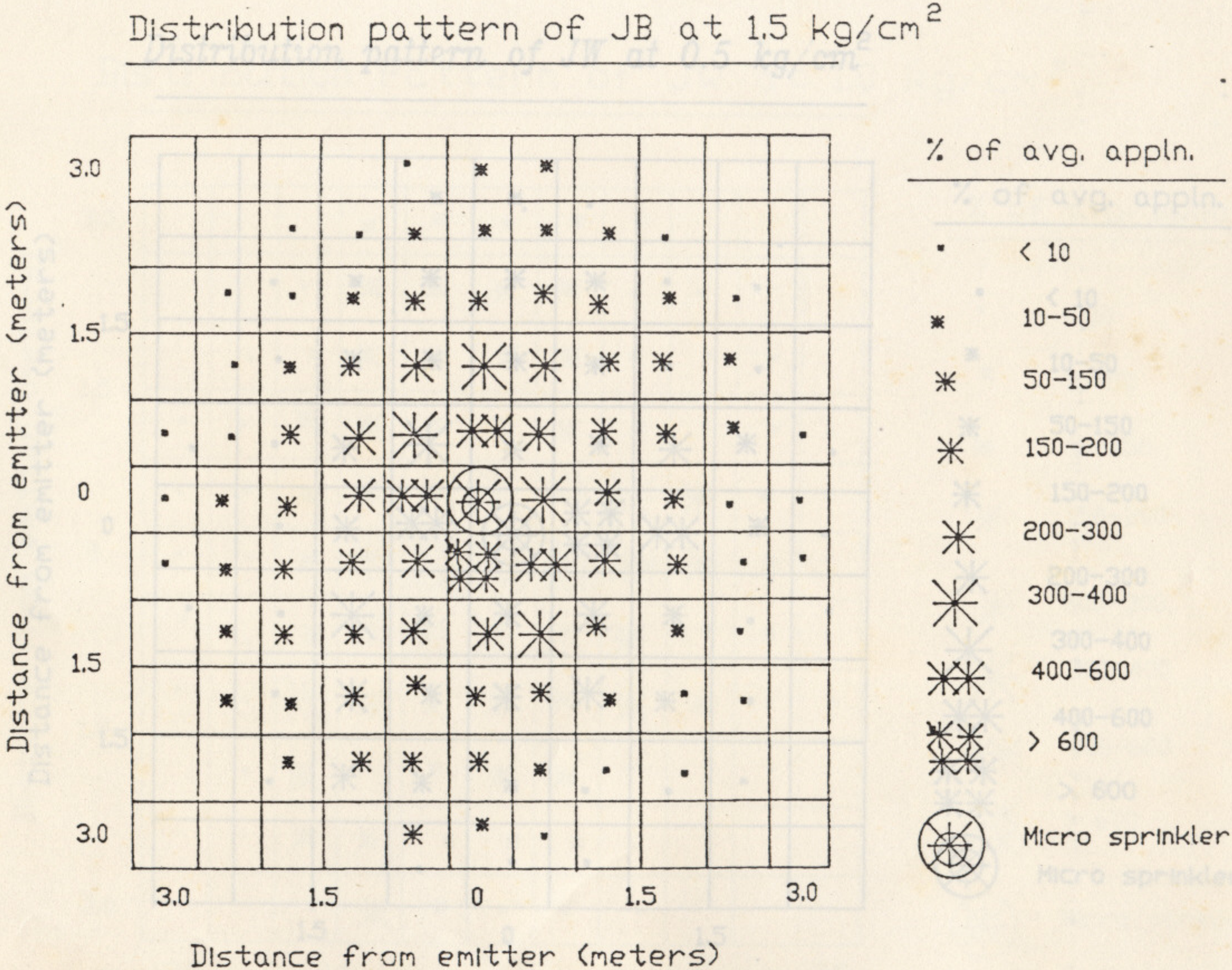


Fig. 8 DISTRIBUTION PATTERN OF JB AT 1.5Kg/cm^2

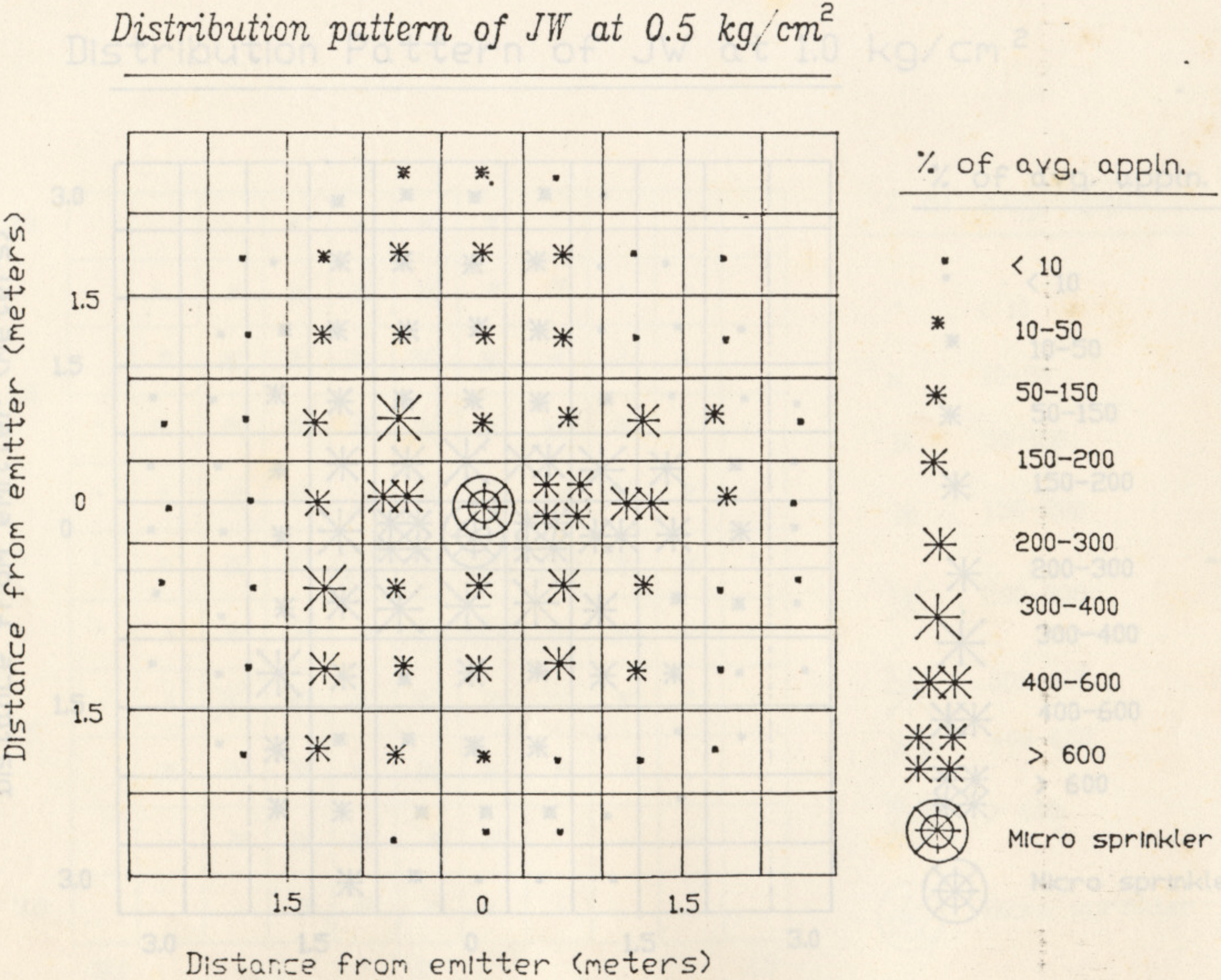


Fig.9 DISTRIBUTION PATTERN OF JW AT 0.5 Kg/cm^2

Distribution Pattern of JW at 1.0 kg/cm²

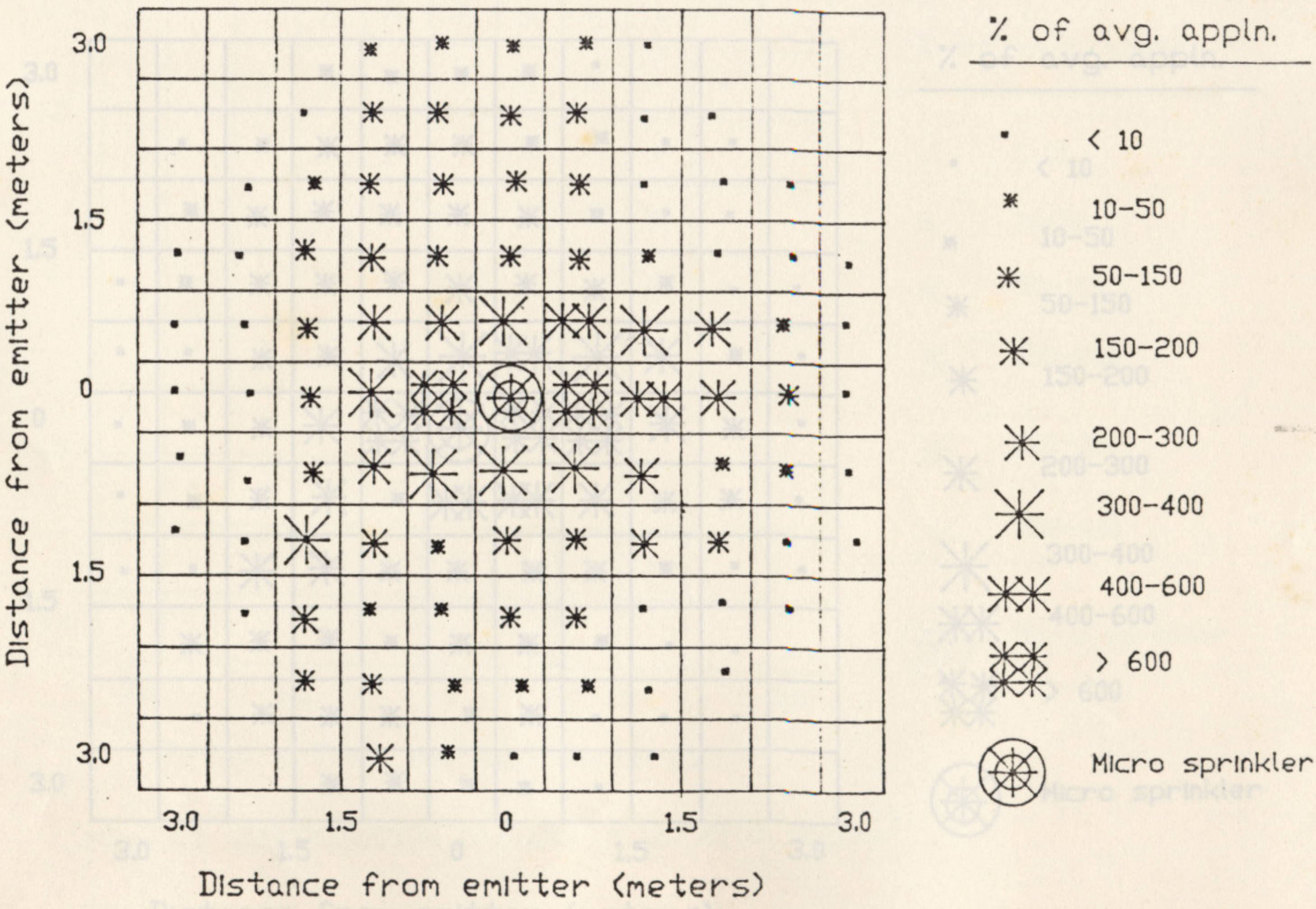


Fig.10 DISTRIBUTION PATTERN OF JW AT 1.0Kg/cm^2

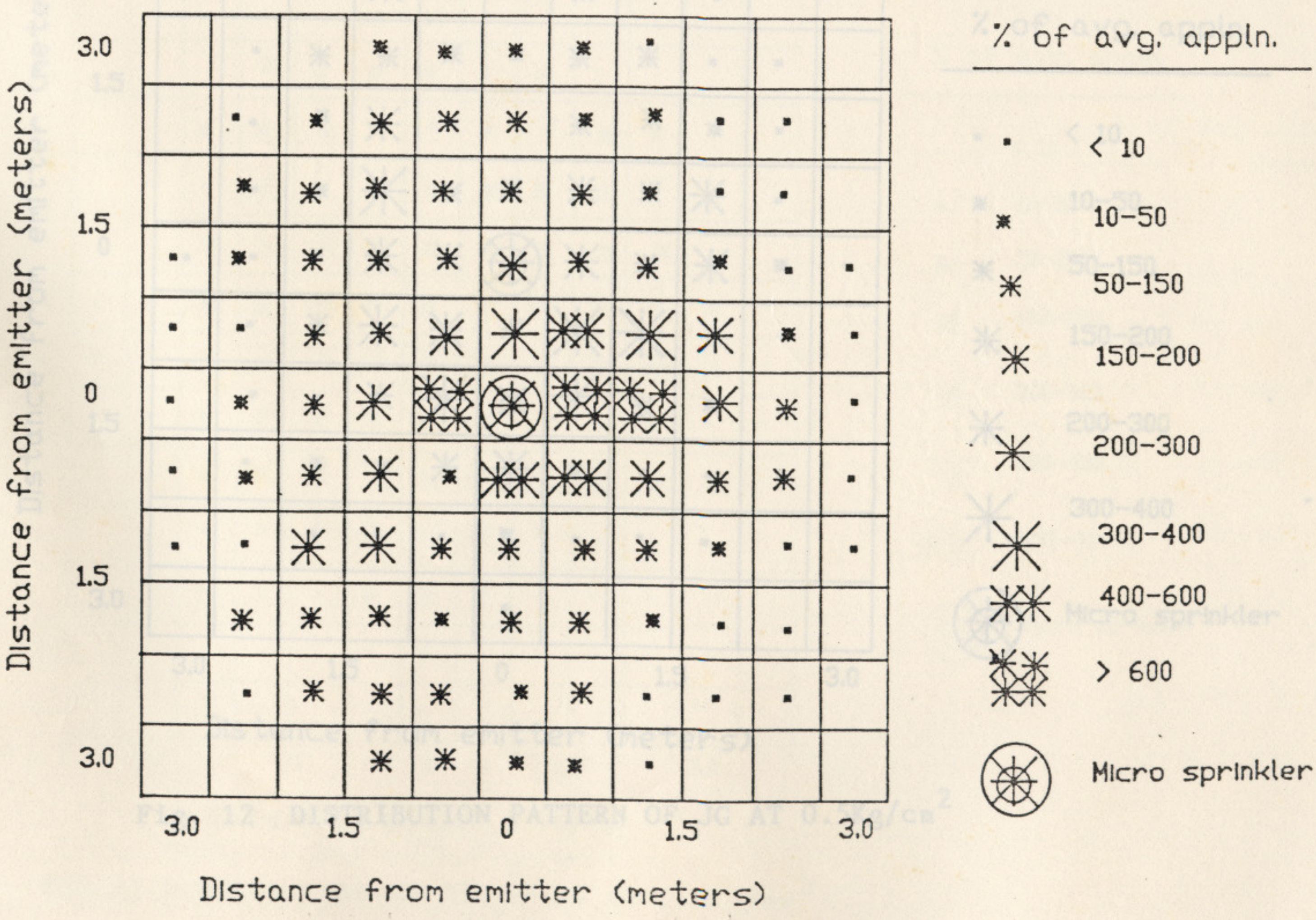


Fig.11 DISTRIBUTION PATTERN OF JW AT 1.5kg/cm^2

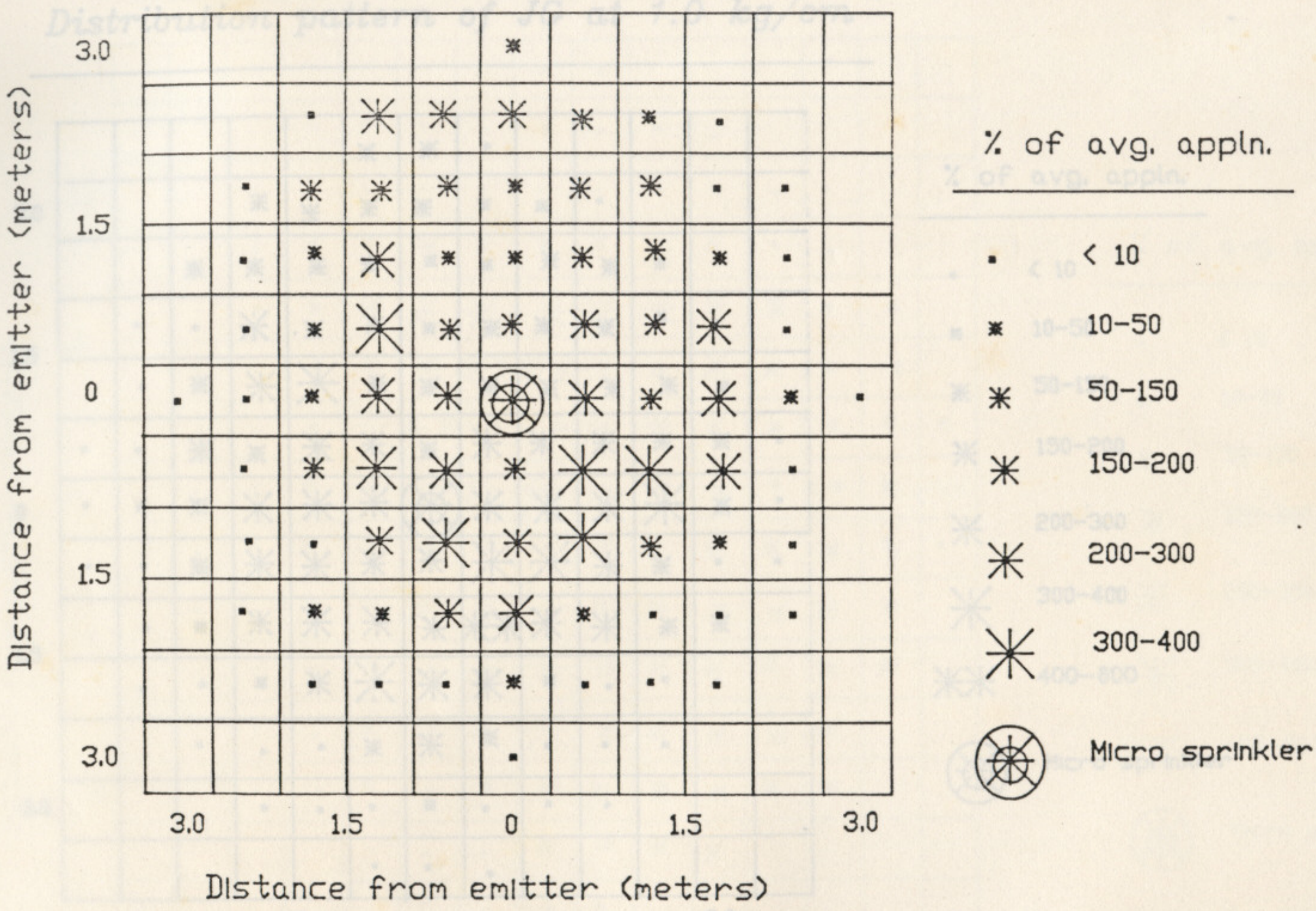


Fig. 12 DISTRIBUTION PATTERN OF JG AT 0.5Kg/cm^2

Distribution pattern of JG at 1.0 kg/cm²

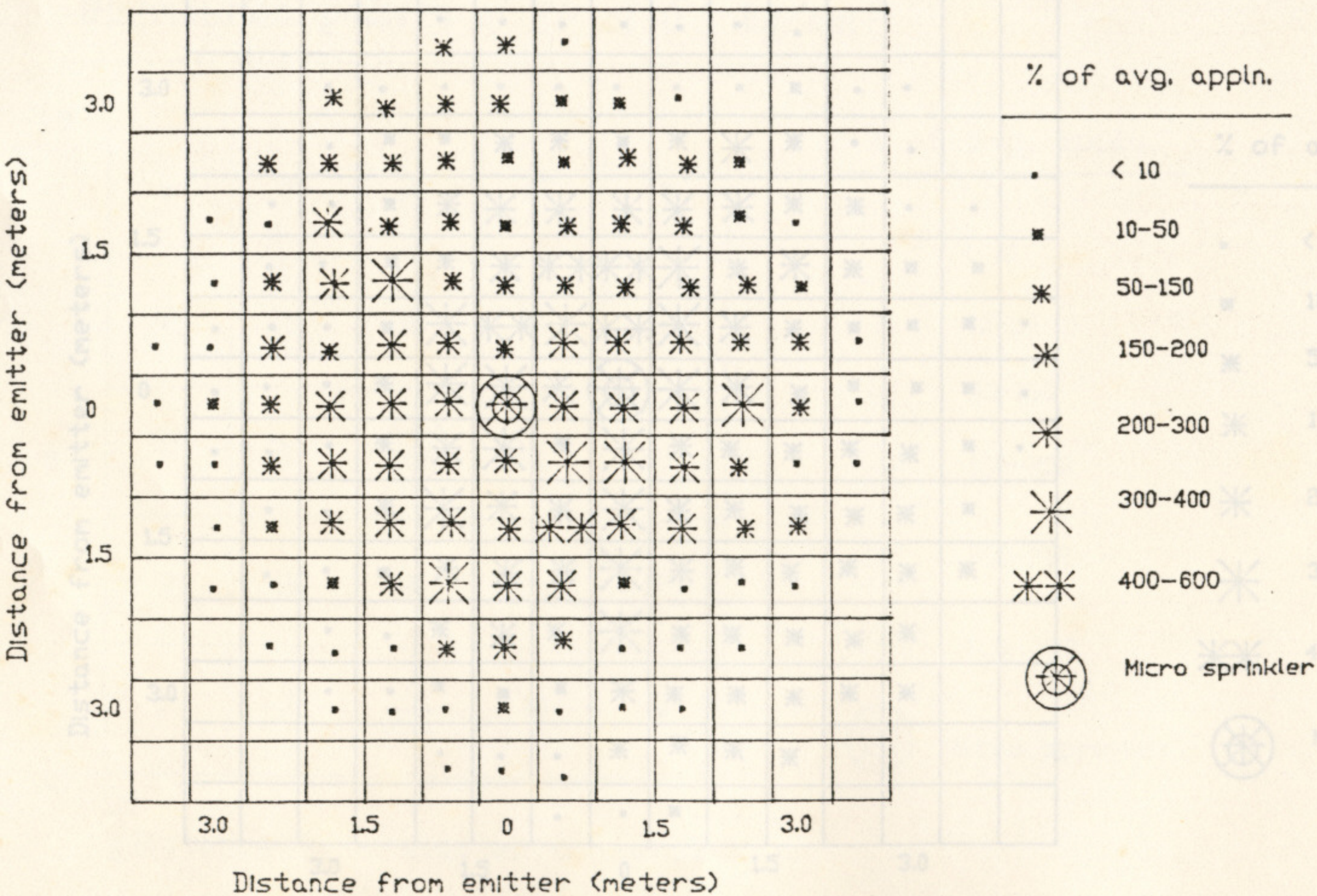


Fig.13 DISTRIBUTION PATTERN OF JG AT 1.0Kg/cm²

Distribution pattern of JG at 1.5 kg/cm^2

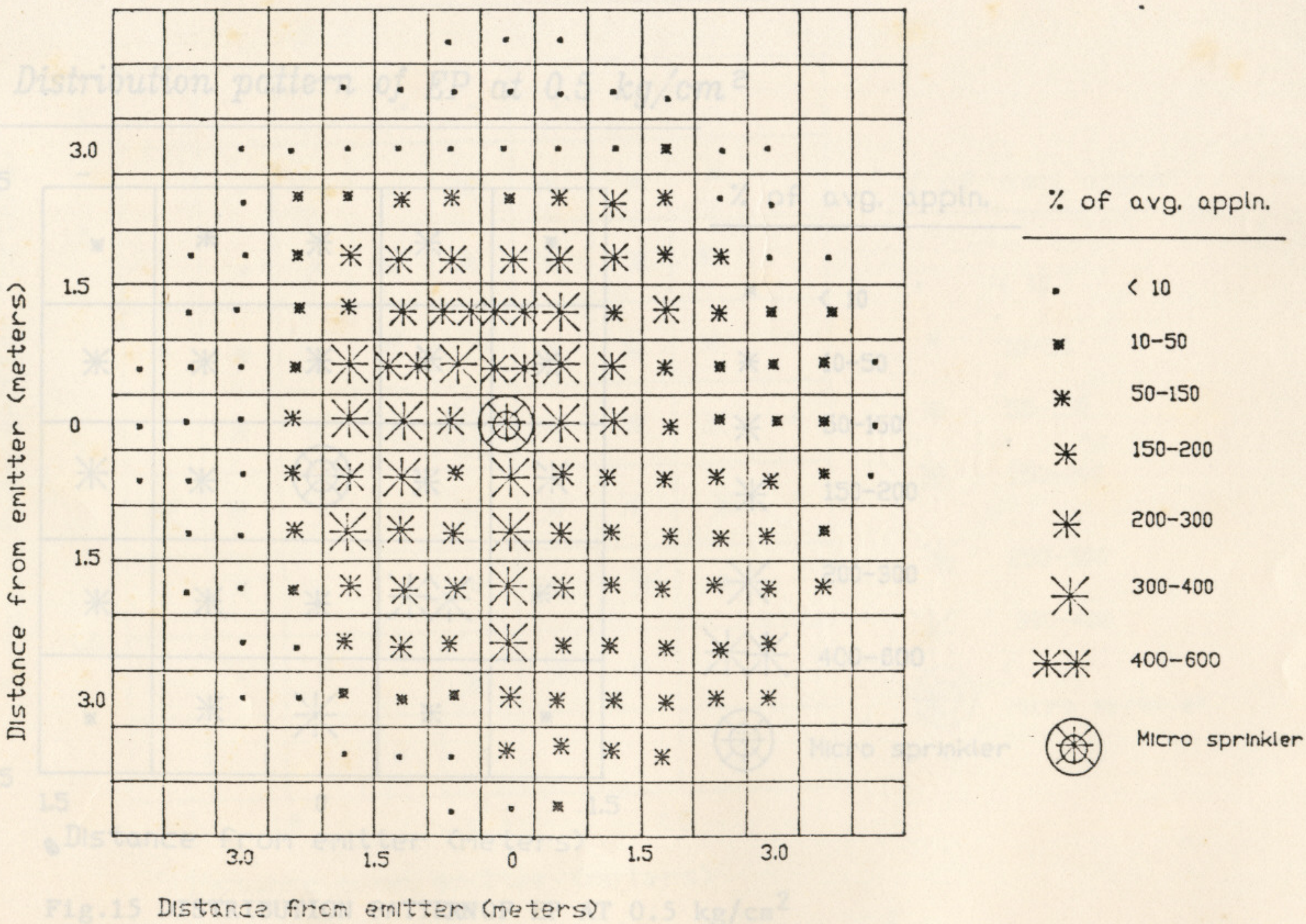


Fig.14 DISTRIBUTION PATTERN OF JG AT 1.5 kg/cm^2

Distribution pattern of EP at 0.5 kg/cm²

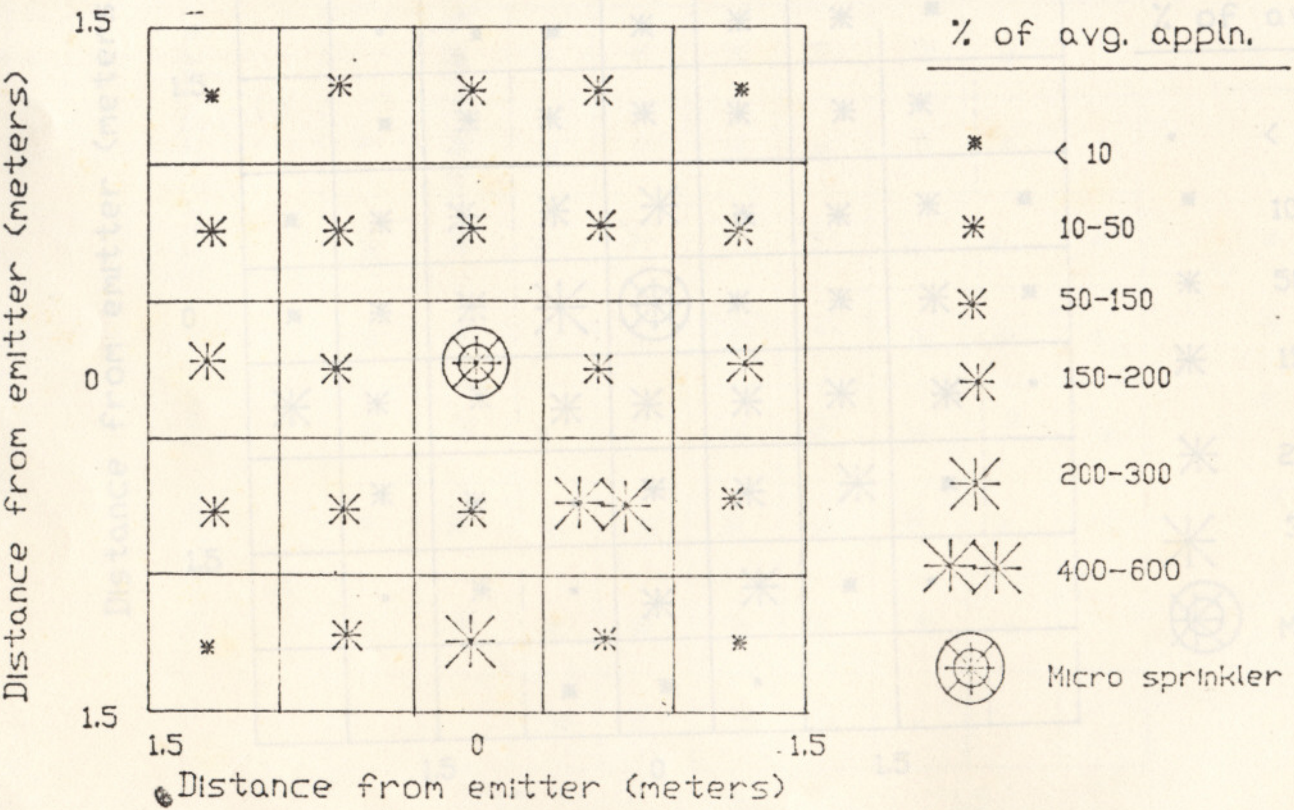


Fig.15 DISTRIBUTION PATTERNOF EP AT 0.5 kg/cm^2

Distribution pattern of EP at 1.0 kg/cm²

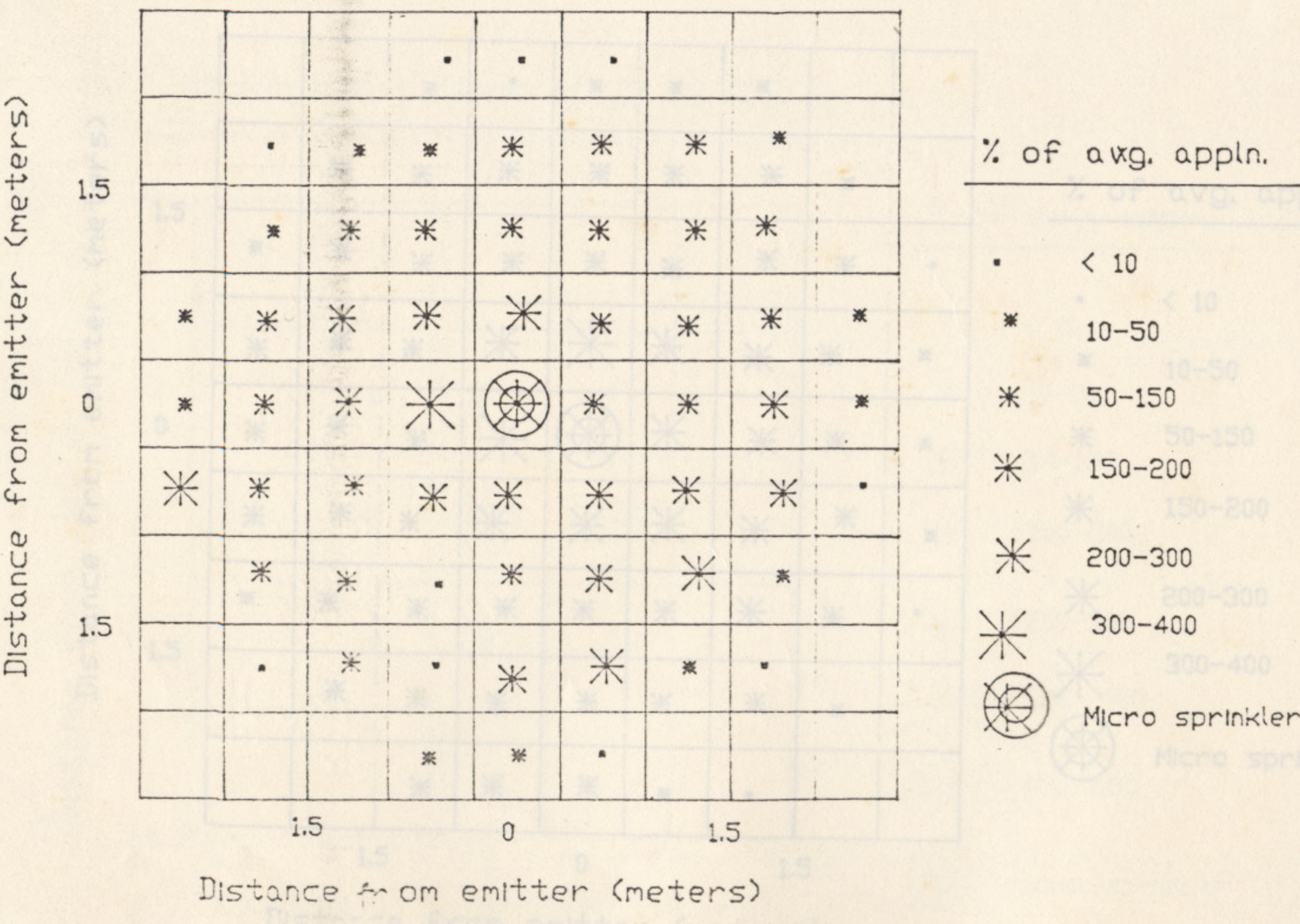


Fig.16 DISTRIBUTION PATTERN OF EP AT 1.0 $kgpcm^2$

Distribution pattern of EP at 1.5 kg/cm²

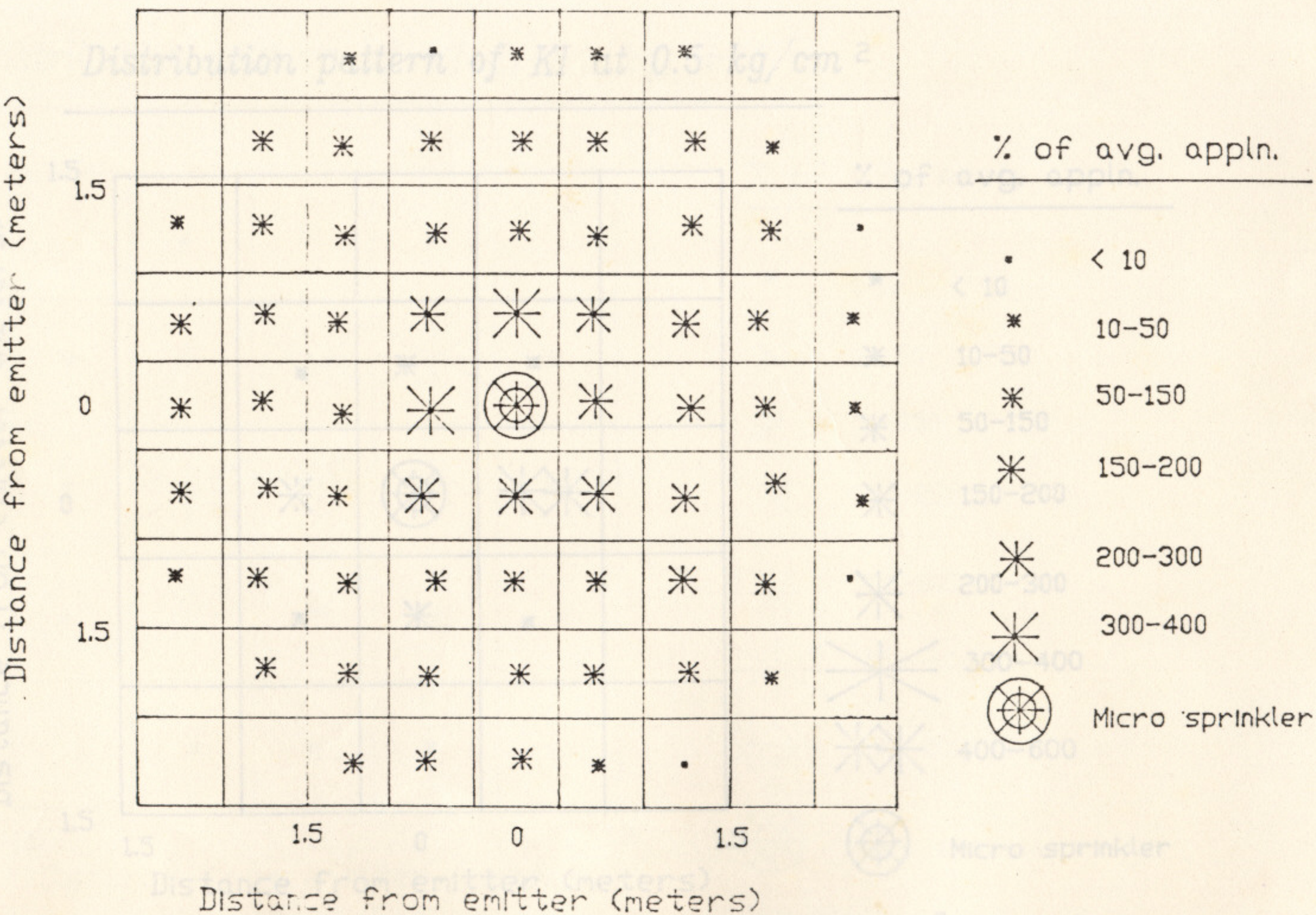


Fig.17 DISTRIBUTION PATTERNOF EP AT 1.5 kg/cm2

Distribution pattern of KI at 0.5 kg/cm ^{2}

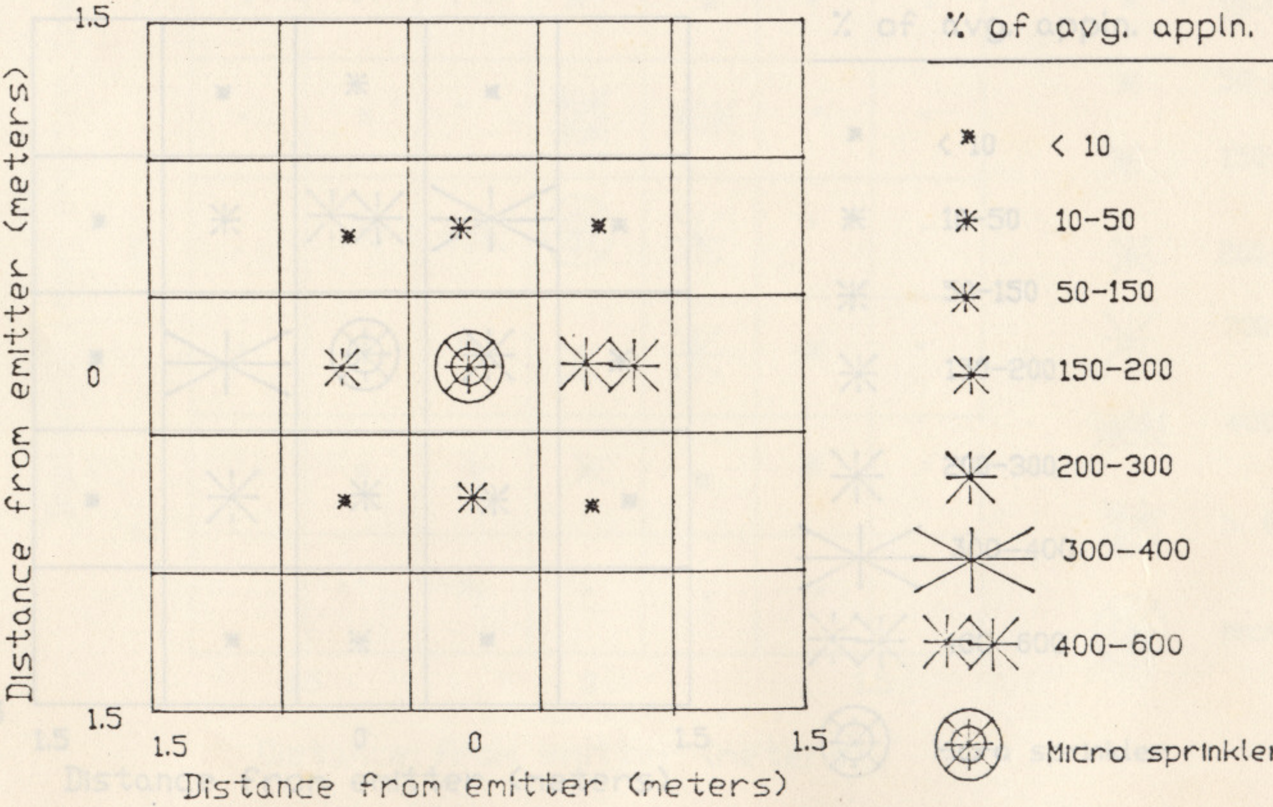


Fig.18 DISTRIBUTION PATTERNOF KI AT 0.5 kg/cm^2

Distribution pattern of KI at 1.0 kg/cm²

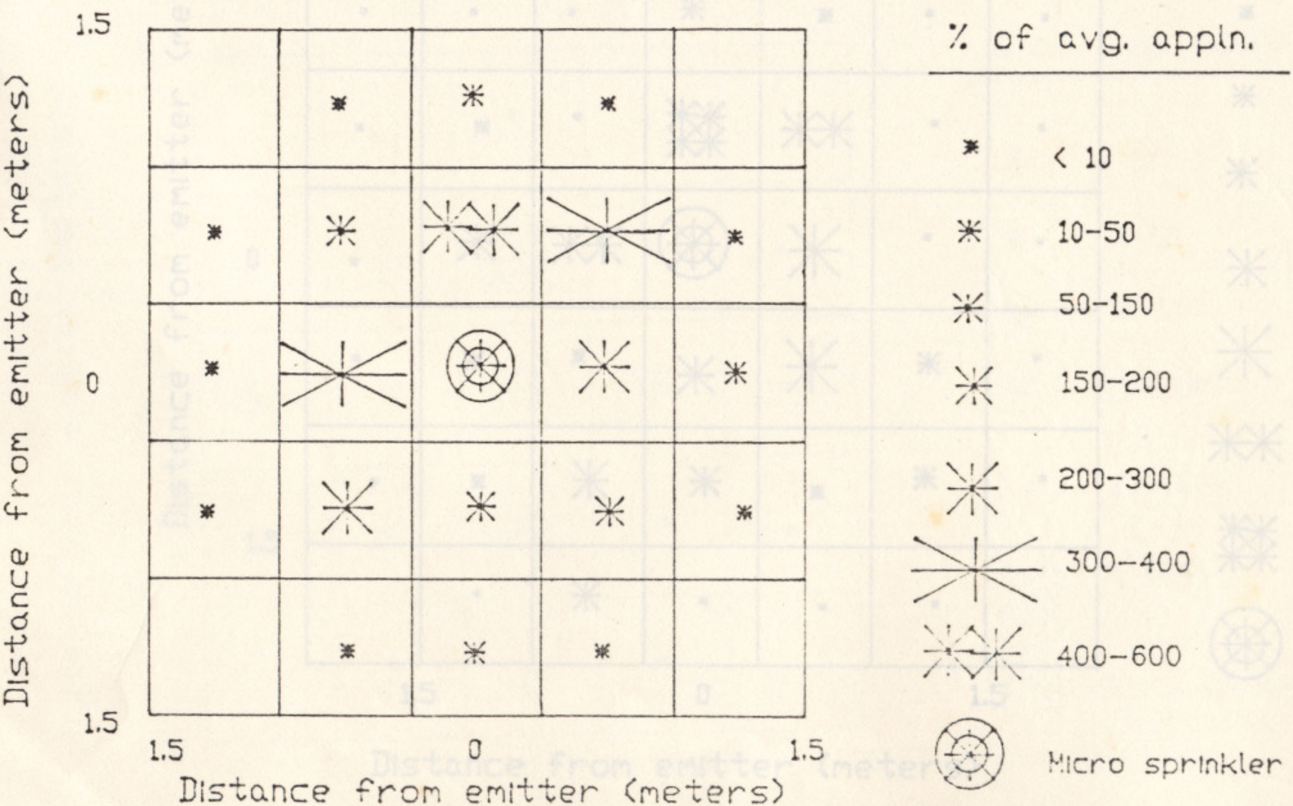


Fig.19 DISTRIBUTION PATTERN OF KI AT 1.0 kg/cm^2

Distribution pattern of KI at 1.5 kg/cm²

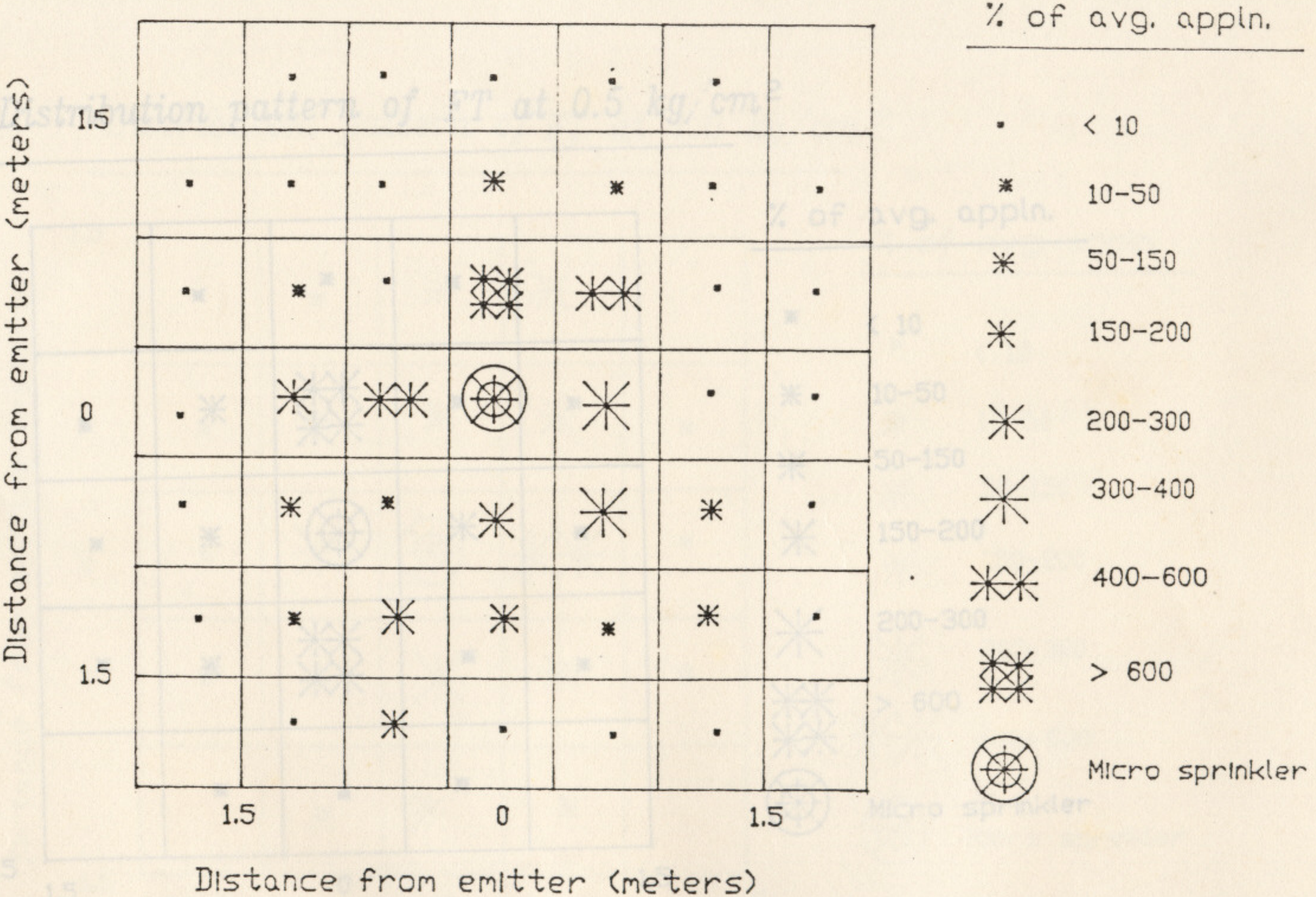


Fig.20 DISTRIBUTION PATTERN OF KI AT 1.5 kg/cm^2

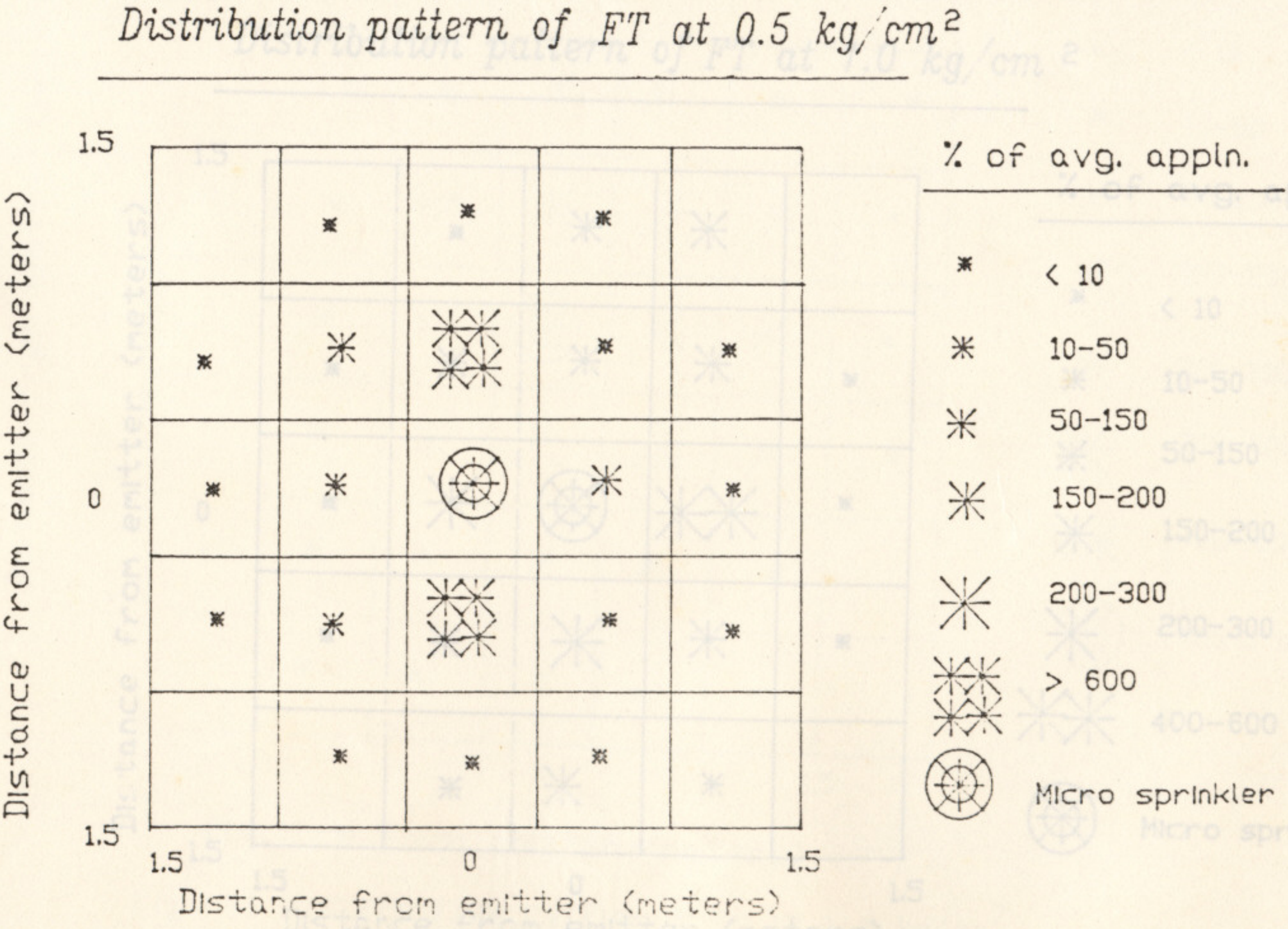


Fig. 21 DISTRIBUTION PATTERN OF FT AT 0.5 kg/cm^2

Distribution pattern of FT at 1.0 kg/cm²

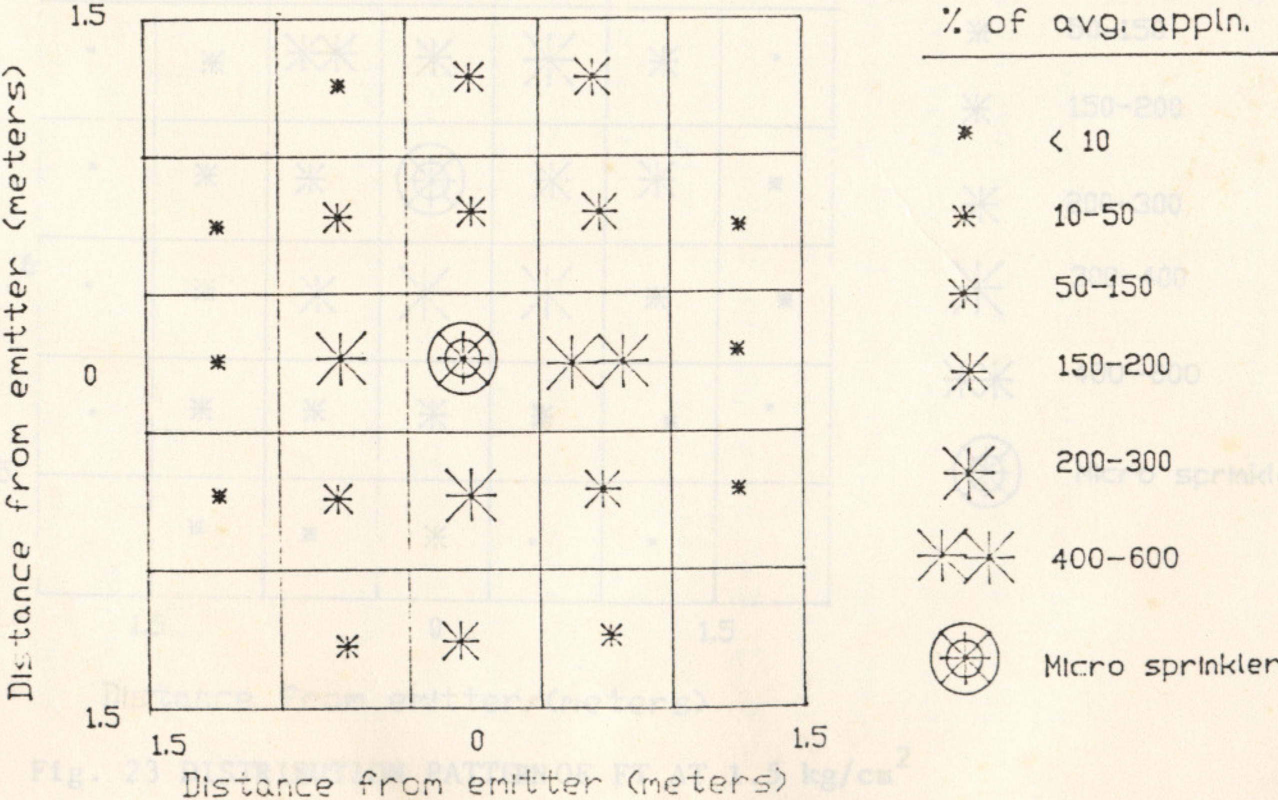


Fig. 22 DISTRIBUTION PATTERN OF FT AT 1.0 kg/cm^2

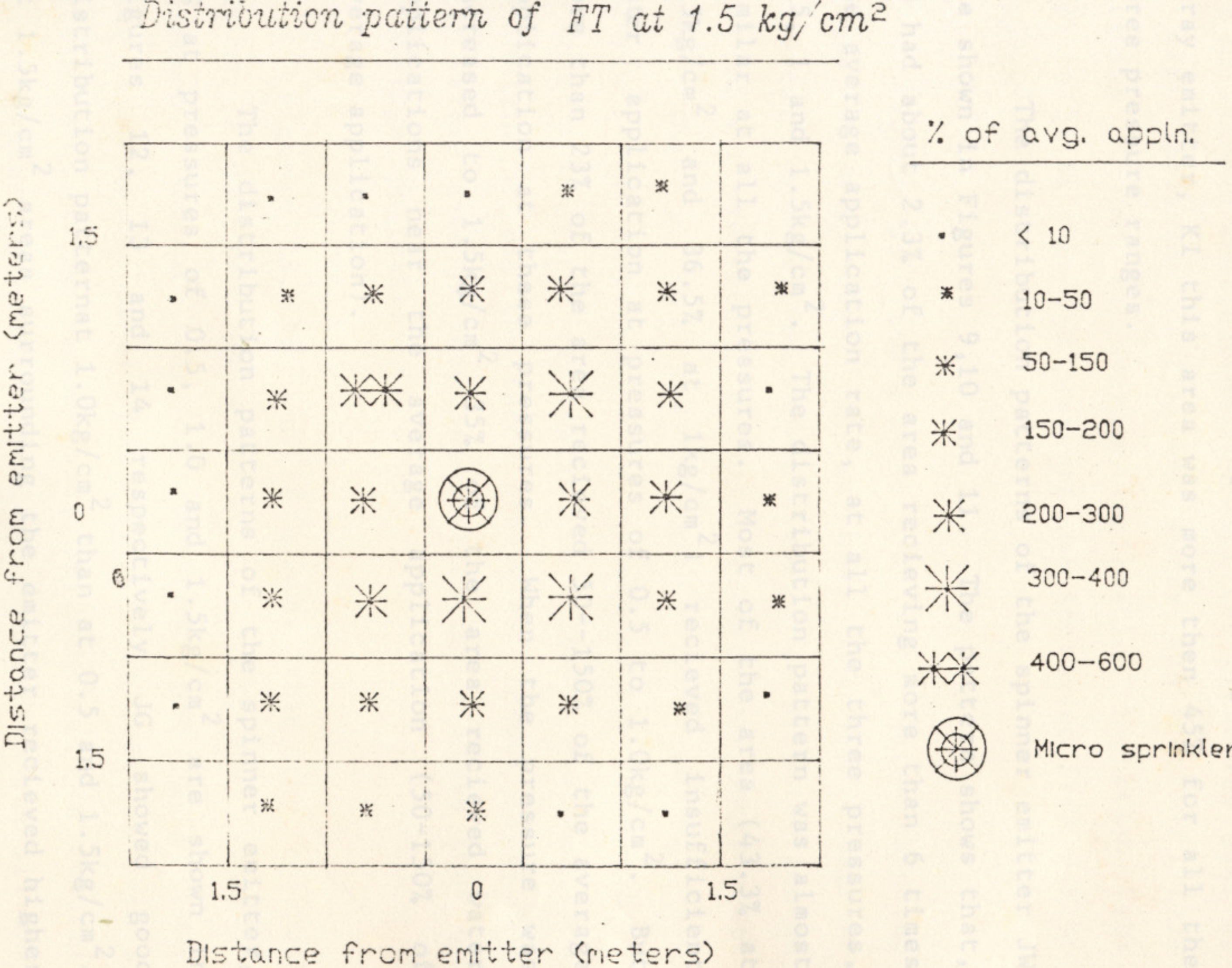


Fig. 23 DISTRIBUTION PATTERN OF FT AT 1.5 kg/cm^2

than 10% of average application while spray emitters had about 46% of the area receiving less than 10% of the average application. For one spinner emitter, EP the area receiving less than 10% of the average application was less than 17% for all the three pressure ranges but for one spray emitter, KI this area was more then 45% for all the three pressure ranges.

The distribution patterns of the spinner emitter JW are shown in Figures 9,10 and 11. The pattern shows that, JW had about 2.3% of the area recieving more than 6 times the average application rate, at all the three pressures, 0.5, 1 and 1.5kg/cm^2. The distribution pattern was almost similar at all the pressures. Most of the area (43.3% at 0.5kg/cm^2 and 36.5% at 1kg/cm^2) recieved insufficient water application at pressures of 0.5 to 1.0kg/cm^2. But more than 23% of the area recieved 50--150% of the average application at these pressures. When the pressure was increased to 1.5kg/cm^2 35% of the area recieved water applications near the average application (50-150% of average application).

The distribution patterns of the spinner emitter, JG at pressures of 0.5, 1.0 and 1.5kg/cm^2 are shown in figures 12, 13 and 14 respectively JG showed good distribution patternat 1.0kg/cm^2 than at 0.5 and 1.5kg/cm^2. At 1.5kg/cm^2 areas surrounding the emitter recieved higher amount of water and most of the water was applied to one side of the emitter and the other sides recieved insignificant amounts of water. At 0.5kg/cm^2 also the pattern was some what non-uniform. More than 30% of the area recieved less than 10% of average application. No part of the wetted area recieved water application above 600% of average application. At all the pressures most of the area recieved insufficient water application. Area recieving 50-150% of average application increased from 18.8% to 27.5% when the pressure was increased from 0.5 to 1.5kg/cm^2.

Figures 6, 7 and 8 shows the distribution patterns of the micro-sprinkler JB at 0.5, 1.0 and 1.5kg/cm^2 pressures. This emitter showed almost good distribution of water at all pressures. A better pattern was obtained at 1kg/cm^2 than at 0.5 and 1.5kg/cm^2 than at 0.5 and 1.5kg/cm^2. the distribution was skewed to two sides and to the other sides water was applied to a lesser distance from the emitter at all the three pressures. About 2% of the total wetted area recieved an application 6 times that of the average application.

Figures 15, 16 and 17 showes that the spinner emitter EP had good patterns at 0.5, 1.0 and 1.5kg/cm^2 pressures. But at 1.5kg/cm^2 pressure, the pattern was better than at the other pressures. EP at 1.5kg/cm^2 had a pattern with a 1m radius area surrounding the emitter recieving about 200-400% of average application and all the other areas except the outer most areas recieving about 50-150% of average application. When compared to the patterns of other spinner emitters EP had the best patterns at all the three pressures.

For JG and EP, there was no area recieving more than 6 times the average application at all the pressures. In the case of EP, more than 50% of the area recieved 50-150% of the average application at pressures of 0.5 and $1.5 kg/cm^2$. So about half of the area recieved water application near the average value. All the spinner emitters had areas recieving more than twice the average application. For spray emitters, about 50% of the effective area recieved insignificant water applications (less than 0.1 time average value for KI and less than 0.5 times Da for FT). One of the spray emitter, FT showed considerable improvement in the distribution pattern when the pressure was increased. In this case the area recieving less than 10% of average application decreased from 70% to 27% the when pressure was increased from 0.5 to $1.5 kg/cm^2$. In the case of KI, about 50% of the area recieved less than 10% of average application at all the pressures. When the pressure was increased from 0.5 to $1.5 kg/cm^2$, the area recieving more than 400% of average application increased from zero to 6.8%.

The distribution pattern of KI at different pressures are represented in figures 18, 19 and 20. In the case of KI, there were some streams depositing higher amounts of water at a considerable distance from the emitter, as shown in figure 18. But most of the area in this case recieved insignificant amounts of water. The distribution pattern was found some what better at $1 kg/cm^2$ than at 0.5 and $1.5 kg/cm^2$.

The spray emitter, FT showed good pattern at $1.5kg/cm^2$ (Figure 23) than at $1.0kg/cm^2$ (Figure22) and $0.5kg/cm^2$ (Figure 21). For this emitter, the pattern showed higher application near the emitter and insignificant water application at other areas, at $0.5kg/cm^2$. For FT, at 1.5 kg/cm^2 also areas near the emitter recieved higher amounts of water and areas within a radius of 2m from the emitter recieved more than 50% of average application.

But for KI, there was no uniform distribution pattern, with some areas near the emitter recieving very high amounts of water (more than 6 times average application) while some area near the emitter recieving insignificant water application (less than 10% of the average application)

In general, spray emitters had a poorer distribution uniformity than the spinner emitters. In the case of spray emitters, most of the area recieved insignificant water applications and some area recieved moroe than 6 times the average application rate. Whereas the spinners applied water near the average application to about 33% of the area.

4.1.4. Distribution Characteristic

Merriam and Kellers distribution characteristic (DC) is the standard method for evaluation for non-overlapping sprinklers. High DC values indicate that

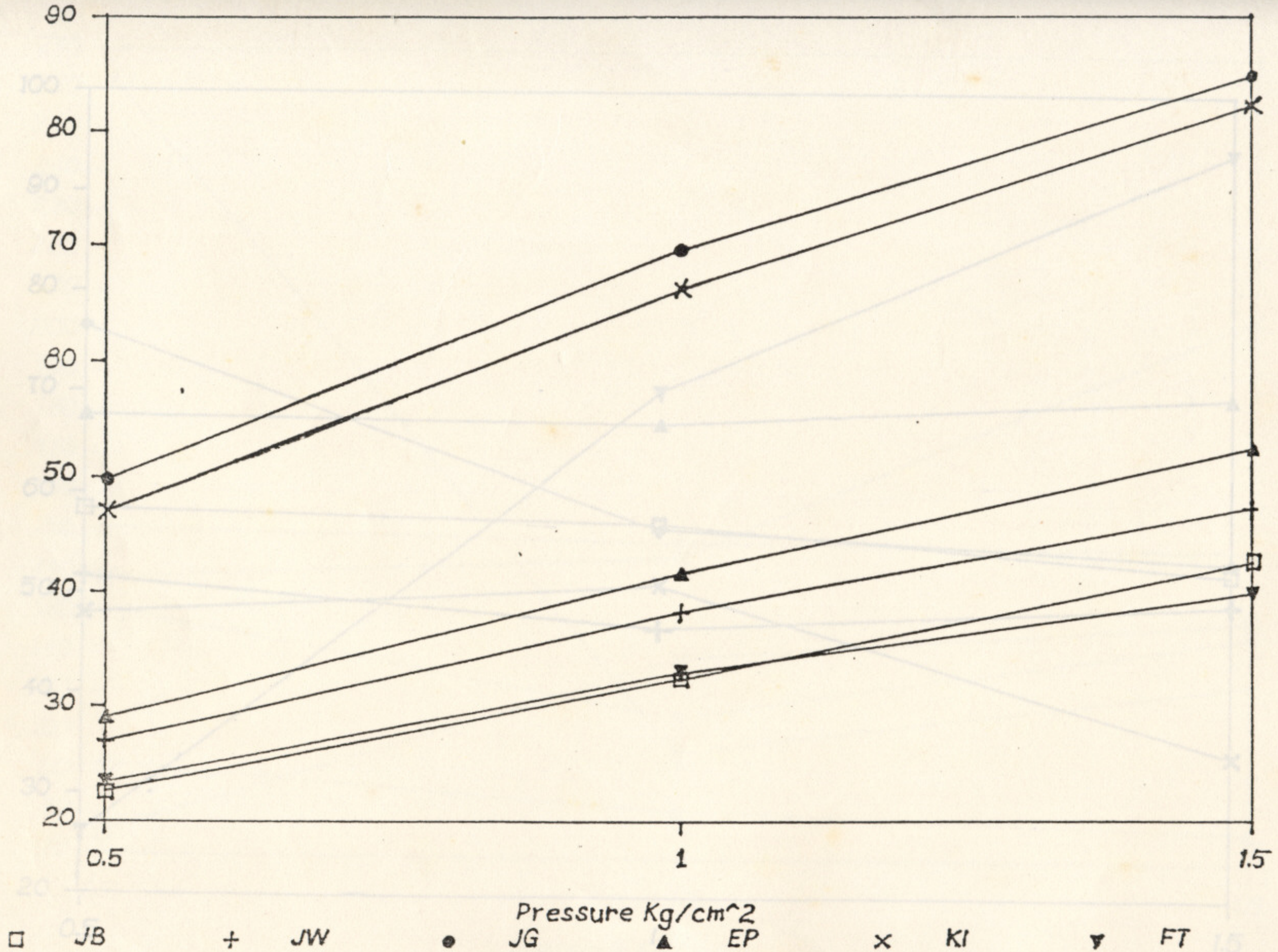


Fig.24 DISCHARGE VARIATION WITH PRESSURE

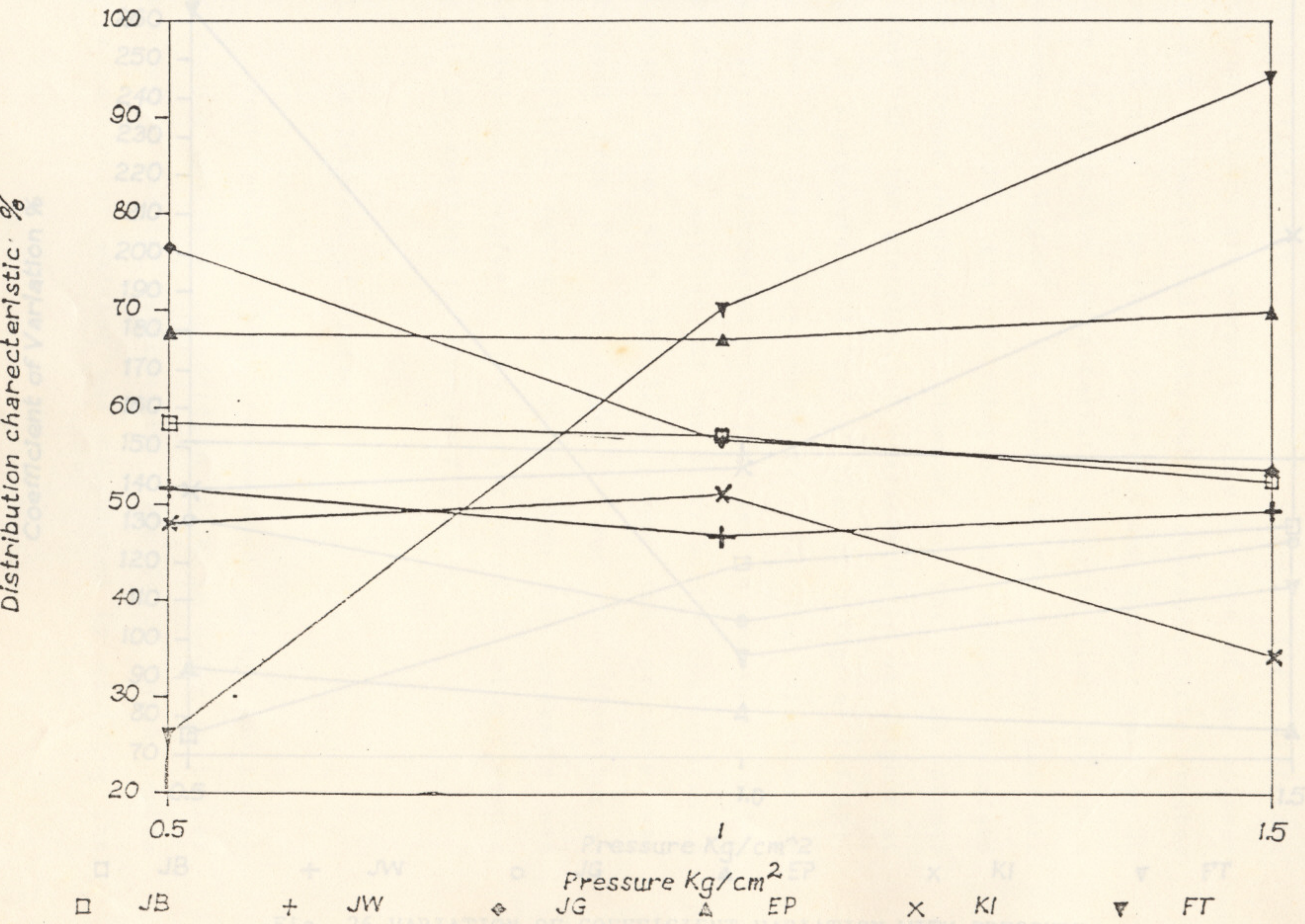


Fig. 25 VARIATION OF DISTRIBUTION CHARACTERISTIC WITH PRESSURE

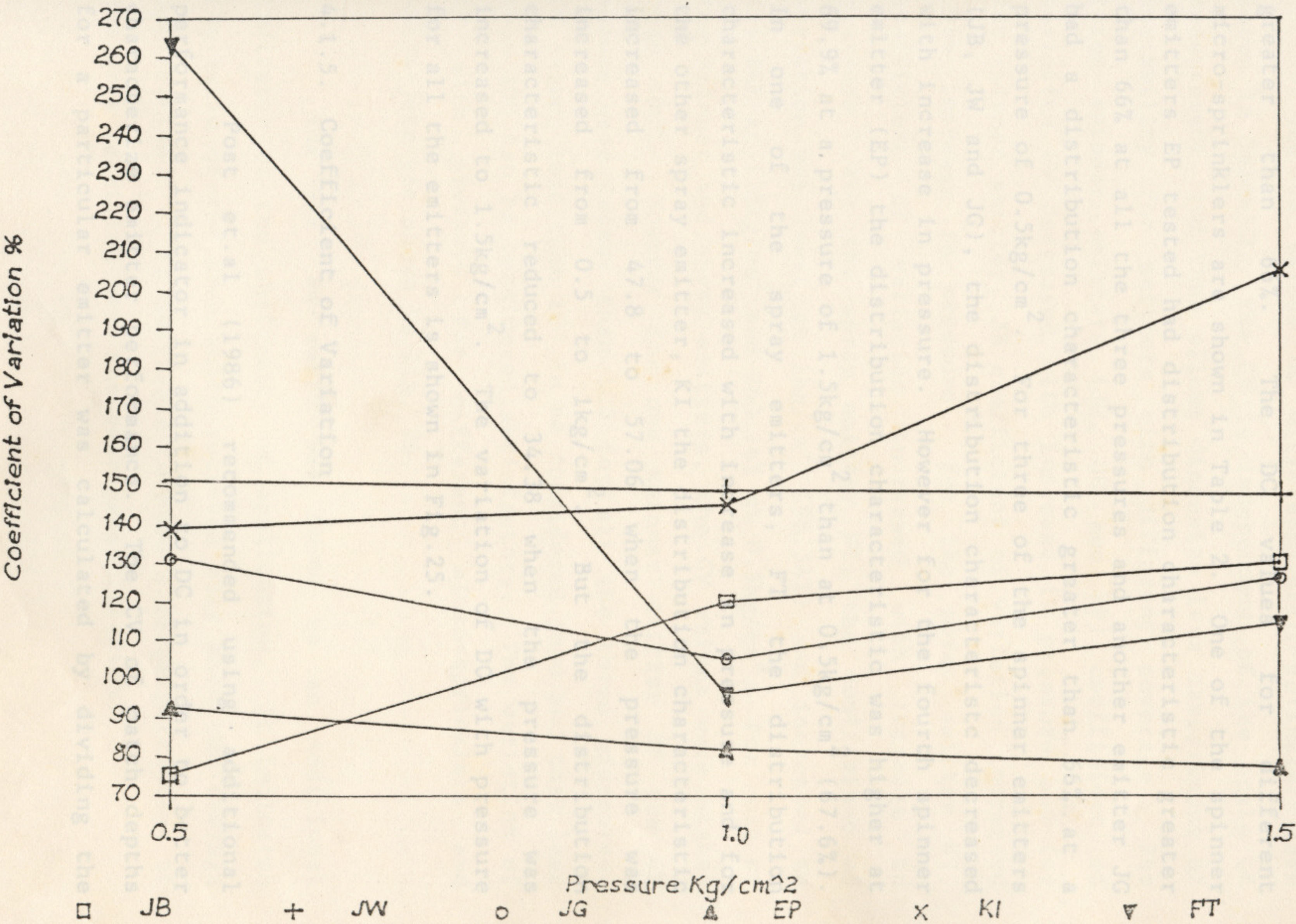


Fig. 26 VARIATION OF COEFFICIENT VARIATION WITH PRESSURE.

the adequately irrigated area is a relatively large fraction of the total area. The DC can approache 100%. However, DC values greater than 50% are probably satisfactory and that very good patterns result with DC's greater than 66%. The DC values for different micro-sprinklers are shown in Table 2. One of the spinner emitters EP tested had distribution characteristic greater than 66% at all the three pressures and another emitter JG had a distribution characteristic greater than 66% at a pressure of 0.5kg/cm^2. For three of the spinner emitters (JB, JW and JG), the distribution characteristc decreased with increase in pressure. However for the fourth spinner emitter (EP) the distribution characteristic was higher at 69.9% at a pressure of 1.5kg/cm^2 than at 0.5kg/cm^2 (67.6%). In one of the spray emitters, FT the distribution characteristic increased with increase in pressure and for the other spray emitter, KI the distribution characteristic increased from 47.8 to 57.06 when the pressure was increased from 0.5 to 1kg/cm^2. But the distribution characteristic reduced to 34.38 when the pressure was increased to 1.5kg/cm^2. The variation of DC with pressure for all the emitters is shown in Fig.25.

4.1.5. Coefficient of Variation

Post et.al (1986) recommended using additional performance indicator in addition to DC in order to better characterize emitter performance. The CV of catch depths for a particular emitter was calculated by dividing the standard deviation of the depths used to calculate the mean by the mean application depth, Da. The CV is expressed as a percentage.

The CV values of different micro-sprinklers are shown in Table 2. The CV is independant of the scale of measurement, and thus allows dimension less camparisons of variability for emitters with different coverage. For three spinner emitters (JW, JG and EP) coefficient of variation CV decreased with increase in pressure and for the spinner emitter, JB coefficient of variation increased with increase in pressure. For the spray emitter KI, coefficient of variation increased with increase in pressure. For the spray emitter FT, the coefficient of variation was least at 1kg/cm^2 (96.34%) and increased to 114.44% at 1.5kg/cm^2 and 263.16% at 0.5kg/cm^2. For most of the spinner and spray emitters, the CV values were higher than 100%. However for one spinner emitter EP the CV values were lesser than 100 for all the three pressures. CV values less than 100 cn be considered good and that less than 200 can be considered satisfactory. The variation of CV with pressure for different micro-sprinklers and micro-jets are shown in Fig. 26.

The Dxe: Da ratio was found as an additional indicator of the uniformity of application. It indicates the ratio of the area which recieved more than the average application. It is desirable to have a large percentage of the area receiving near the average application.

In the case of two spinner emitters (JW and EP) Dxe: Da ratio decreased with increase in pressure. In the case of one spinner emitter JB Dxe:Da ratio increased with increase in pressure. For the spinner emitter JG, Dxe : Da ratio decreased from 5.25 to 3.74 for a pressure increase from 05-1kg/cm^2 and increased to 6.03 for an increase to 1.5kg/cm^2. For one Spray emitter FT Dxe : Da ratio decreased with increase in pressure and for the other spray emitter KI, the ratio increased with increase in pressure.

4.1.6. Discharge

The discharge of the spinner and spray emitters were determined at pressures of 0.5, 1 and 1.5kg/cm^2. The discharges of both spinner and spray type emitters increased with increase in pressure. The discharges vary from 22.61 ltrs/hr to 84.58ltrs/hr for the spinner type emitters and from 23.37lph to 82.01lph for the spray type emitters. The variation of discharge of different emitters with the operating pressure is shown in fig.24

4.2. Design and development of a pulsating micro-sprinkler irrigation system

The micro-sprinkler system and control board for the pulsating irrigation were designed and developed as described in chapter 3. The system was installed by the first week of september and tested for three months. It was found that the system was working excellently well.

The system was designed to apply only the sufficient quantity of water to meet the evapotranspiration requirements of the plants, after taking into consideration the losses during the application. The water requirement of the plants for the months of September, October and November where determined after finding their ET requirement and the application losses. The pulsation rate of the system was adjusted to apply the required amount of water needed for the plants in a day, during the total irrigation time in a day which was kept at 8 hours. The application rate of the emitter used was 8.85mm/hr and it was required to achieve an appliction rate less than 1mm/hr. It was found that an on-time of 2 minute and off time of 22 minutes in a pulse, during the month of september gave an application rate of 0.71mm/hr while applying the required amount of water to the plants. The on-delay was made 22 minutes and off-delay 2 minutes during the month of October to give an appliction rate of 0.59mm/hr, while applying the water required to meet the plant ET in a day. The on-delay and off-delay were changed to 19 minutes and 2 minutes respectively during the month of November. The water requried to meet the ET requirement of the plant per day was applied during 8hrs. of irrigation at a time averaged appliction rate of 0.84mm/hr.

There was no stress to the plant since the field was wet all the time. The plant response to the irrigation was good which was indicated by its vigorous growth. The plants flowered quickly under this irrigation system. The results obtained showes that pulsating micro-sprinkler system can be successfully used for irrigating gardens.

SUMMARY AND CONCLUSION

An experimental study to evaluate the performance of micro-sprinkler heads-both spinner and spray type emitters-under different operating pressures was conducted at KCAET campus, Tavanur. The micro-sprinkler head were operated at the centre of a closed room with collectors arranged in a grid around the emitter.

The testing procedure consists of setting up a pattern of catch cans; operating the micro-sprinkler for a period of time, during which the operating pressure and the rate of discharge were observed, and the measurement of catch in each collector at the conclusion of the period. From the volume collected in the cans, the depths of application, radius of throw, distribution pattern, distribution characteristic and coefficient of variation were determined.

Traditional concepts of uniformity evaluations are difficult to apply to micro-irrigation spray and spinner emitters. Unlike most sprinkler applications, these emitters are normally used in a non-overlapping manner where a flat distribution over the entire wetted area is desirable. Most of the spray type emitters applied water in distinct streams or spokes. These spoke patterns made it difficult to appropriately describe performance parameters such as coverage area and average application depths.

It was quite evident, however, that the spinner type emitters had significantly higher distribution uniformities than spray emitters. The spinners were much more successful in distributing the water. They generally applied water to more than 85% of the effective area. Dough-nut patterns, however were more pronounced in some spinner models when they were operated at low pressures.

The CV of the catch depths was selected to be the most appropriate performance indicator for these emitters. CV values less than 100 for these type of emitters can be considered as 'good' water distribution. CV val es over 200 indicate patterns that have a large portion of the effective area that receive no water. These high CV's may also signify that the pattern has areas with very high application depths relative to the mean.

In a field setting, the uniformity of the emitters may be affected by climatic conditions, maintanance state, all factors relating to the system design and installation. When selecting particular emitter for an installation, one must be aware that emitters have different performance characteristics. The emitter selection process should consider uniformity as well as other factors such as cost, wind effects, system constraints, maintanance and soil type so that the best emitter for a particular field condition is selected. Hence this study helps to select the appropriate emitter for the pressure head and uniformity of application desired.

An experimental study to design and develope a pulsating micro-sprinkler irrigation system was also conducted at KCAET, Tavanur during the months from August - November, 1992. The system was tested on different varieties of flowering plants in a small garden. The infiltration rate of the soil in the site was measured to determine the maximum application rate possible. According to previous works an application rate of 0.5-1.5mm/hr was found desirable for good aeration and better soil-water-plant relationships. An application rate less than 1mm/hr was achieved by suitably adjusting the width of the pulse.

The pulsation rate was adjusted for each month to apply the right amount of water to meet the Evapotranspiration(ET) requirements of the plants, within the total irrigation time in a day. The ET requirement of the plants for the months of September, October and November were determined. The pulsation rate for each month was found after considering the water requirement of the plants for the month, including application losses, total time of irrigation in a day and the time averaged application rate desired. The average application rate was kept below 1mm/hr and the total time of irrigation in a day was 8hrs. The application rate of the emitter (microjet) was 8.85mm/hr. The on-time and off-time for a pulse in the month of september was 2 minutes and 23 minutes respectively, which gave an average application rate of about 0.71mm/hr. The application rate was kept at 0.59mm/hr for the month of October by giving an on-time of 2 minutes and off-time of 22 minutes in a pulse. In November the on-delay and off-delay where 19 minutes and 2 minutes respectively, giving an application rate of 0.84mm/hr.

The system behaved as if the time averaged application rate was being continuously applied. The soil was always wet due to the closeness of the wetting cycles. This reduced moisture stress to the plants which was indicated by their improved growth. So the system allowed the use of high discharge emitters while still effecting a low infiltration rate.

High frequency, low depth of irrigation was obtained with the pulsation of the micro-ject irrigation system. Hence losses of water and nutrients below the root-zone would be prevented by making use of this system. water equal to the ET requirement of the plants was applied and the concept of soil as a moisture reservoir was discarded. The micro-jet wetted whole of the root volume and provided sufficient cooling required for the garden plants. This helped better development of the root system and better nutrient reserve for the plant. Hence the pulsating micro-sprinkler irrigation system was able to supply sufficient water to meet the ET requirement of the plant without evaporation and deep percolation losses and providing a better aeration to the soil. The system was tested in the field for 3 months and the plant response to the irrigation was found good. Vigourous growth and early flowering of the plants were observed.

It is probable that the need for higher yields per unit of water which can be achieved by using a relatively low application rate (1mm/hr and less) will lead to a wider use of pulse irrigation and the correct determination of the pulse characteristics enables the efficient use of this technique.

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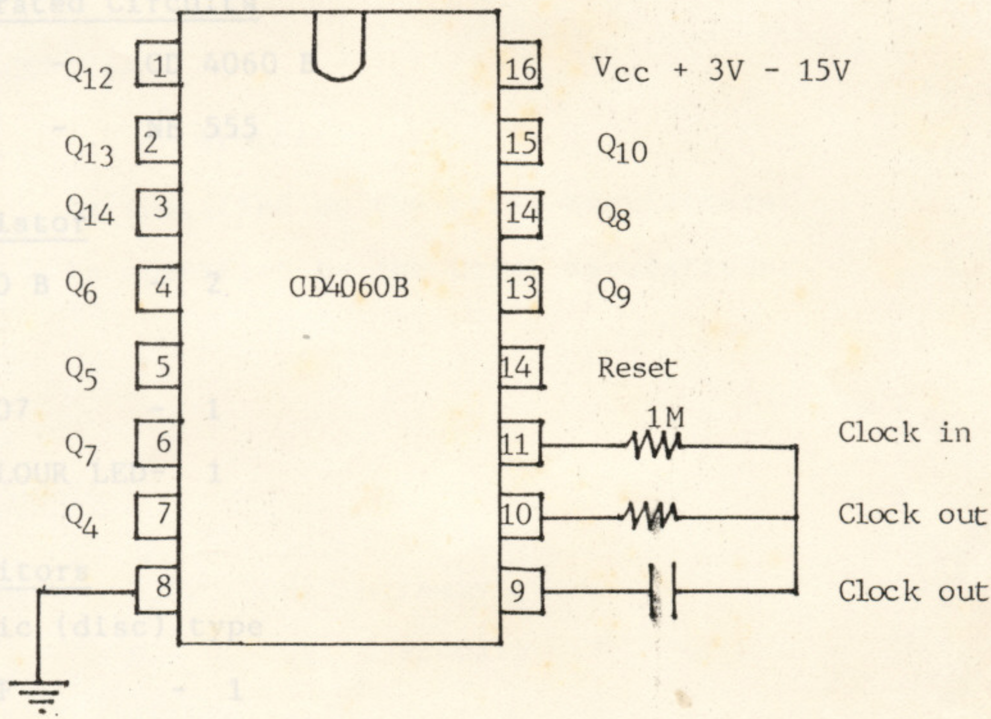
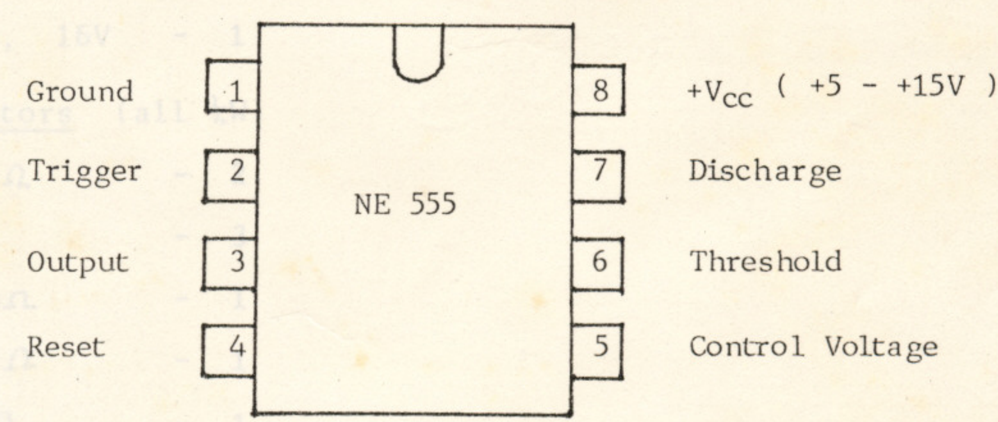
endix.1 PIN CONFIGURATIONS OF CD4060B AND NE555



Q_4 - - - Clock frequency divided by 2^4

- -

Q_{14} - - - Clock frequency divided by 2^{14}



Appendix.II LIST OF COMPONENTS

Integrated Circuits

IC 1 - CD 4060 B

IC 2 - NE 555

Transistor

SL 100 B - 2

Diode

IN 4007 - 1

BI-COLOUR LED - 1

Capacitors

Ceramic (disc) type

0.1 μF - 1

0.01 μF - 2

0.22 μF - 1

Polyster type

0.47 μF - 1

Electrolytic type

47 μF, 16V - 1

Resistors (all ¼W)

100 KΩ - 2

1 KΩ - 3

1.2 MΩ - 1

1.5 KΩ - 1

10 KΩ - 1

270Ω - 1

470Ω - 1

Variable Resistors

1 M	-	2
1 K	-	1

Triac 400V, 6A

R_s & C_s - Snubber

R_s = As specified by the trial manufacturer

C_s = As specified by the trial manufacturer

Power Supply

Transformer	230V, 50Hz primary
	9 - 0 - 9V Secondary
Diode	IN 4007 - 2
Integrated Circuit	9V regulator

DEVELOPMENT AND EVALUATION OF A PULSATING MICRO-SPRINKLER IRRIGATION SYSTEM

By

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ABSTRACT OF PROJECT REPORT

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ABSTRACT

Micro sprinkler irrigation is a water saving method of irrigation. To attain efficient irrigation, the system has to be operated at the correct operating pressure. The present study was conducted to evaluate the performance of different types of micro sprinkler heads under different operating pressures. When selecting particular emitter for an installation, one must be aware that emitters have different performance characteristics like the distribution pattern, the distribution characteristic, coefficient of variation, wetted diameter and application rate which will give an overall idea about the performance of microsprinklers.

Four micro sprinkler heads (spinner type) and two microjects (Spray type) were tested at pressures of 0.5, 1 and 1.5kg/cm^2. The entire area of the micro sprinkler spread was divided into square grids and collectors were placed at the centre of the grids.

The distribution pattern of different emitters at pressure of 1.5, 1,& 0.5kg/cm^2 were drawn to represent the percentage of average application depths collected at different distances from the emitter. This will give an idea about the uniformity of application of a particular emitter.

The ratio of effective maximum application depth to mean application depth for different sprinklers at different operating pressures were found. In the case of spinner emitters most of the area received water in the range of 50 to 150 percent of the average application depth. In the case of spray emitters, most of the area recieved less than 10 percent of the average application depth of water.

The wetted diameter and the discharge of all the emitters increased with increase in pressure. The discharge varied from 22.61 to 84.58 lit/hr for spinner emitters and 23.37 to 82.01lit/hr for spray emitters at different pressures.

The distribution characteristic was used as the parammeter to express the uniformity. The distribution characteristic was found to be satisfactory for all the emitters. An additional parameter which was used to express the uniformity of application was the coefficient of variation. Most of the emitters had a satisfactory coefficient of variation.

Now a days mocro-sprinkler irrigation is achieving widespread recognition in India due to its high efficiency and cheap cost in long term. Pulsation of micro-sprinkler irrigation, in addition to increase in yield, offers unquestionable savings of valuable resources such as water, energy, chemicals and labour. The present study was conducted to design and develop a pulsating micro-sprinkler irrigation system and to test the system performance in a small garden. The system was tested for three months September, October and November 1992. The pulsation rate was varied for different months to meet the crop evapotranspiration requirement. The system was found to perform well, as indicated by the vigorous growth of the plants.