Development of a Prototype Dehuller for Pretreated Chickpea

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Abstract

A prototype machine was developed for dehulling of pretreated pulse grain. The dehulling unit consists of an abrasive roller and a stationery concentric perforated mesh drum over it. The separation of hull and splitting of chickpea grain was effected by abrasive action and shear forces caused on the grain when the roller rotates in the drum. The machine was tested using conventional and improved grain pretreatment methods. A dehulling index of 0.93 and dhal recovery of 78 percent were obtained with improved pretreatment method.

Introduction

Pulses are among the ancient food crops with evidence of their cultivation for over 8000 years. Besides being a rich and the cheapest source of dietary protein and a valuable animal feed, they also play a key role in improving and sustaining soil productivity. About 15 percent of the dietary protein is met from pulses in India as compared to 9 percent in Asia, and 7 percent in the world. They not only add to the quantity of protein in the diet but also improve its quality by balancing the essential amino acid pattern in the mixed diets. Chickpea is the most important pulse crop of the Indian subcontinent, accounting 47 percent of the total pulse production from 33 percent of the total pulse area. Generally, chickpea is consumed in the form of dehusked splits (dhal) or besan obtained from the dhal. Removal of the seed coat reduces roughage, improves storability and palatability for consumption in various forms. It also improves soaking, cooking quality and digestibility.

The dehulling of chickpea has emerged as a large scale value addition commercial operation, from a small scale traditional process. It is estimated that about 50 percent of the chickpea dehulling is still carried out on a cottage industry level by the farmers and small retailers either traditionally using stone chakki or mechanically using dehullers. Several small millers process 100 to 500 kg of grain per day either for trade purpose or custom hiring basis as a home scale operation.

The traditional stone chakki method is a slow and very laborious process. The dehulling technology of chickpea, at the small scale commercial level involves two basic operations, i.e. loosening of the husk by soaking the grain 5-6 hours followed by sun drying that splits the grain into cotyledons using emery coated disks and rollers. Abrasive dehulling is much faster and less tedious, but it causes excessive breakage losses of cotyledons in the hull fraction, yielding a low quality end product with more losses. Prolonged soaking of the chickpea grain in water also causes cup formation in cotyledons resulting in poor quality dhal. Hence, there is a great demand from the traditional pulse processors to upgrade their existing milling machinery and improve pretreatment procedures.

Chickpea can be dehulled with less loss and higher quality dhal than is possible with current mechanical dehullers if proper pretreatment methods and dehulling equipment could be developed. Pretreatment such as wet or dry conditioning have been used for centuries in pigeonpea dehulling with great success in the traditional dehulling system to facilitate the removal of seed coat and splitting of cotyledons. The pretreatments followed in pigeonpea should not be followed as it is, because, it is considered hard to mill grain compared with chickpea. Hence, incorporation of some of the underlying principles commonly used in traditional dehulling system using mechanical dehulling machinery could lead to less breakage of chickpea during the dehulling process due to loosening of seed coat from the cotyledons.

Attempts have been made to develop small scale dehullers (capacity ranging 100-150 kg/hour) for pretreated pulse grain but with little success so far. Lal et al. (2004) developed a small capacity dhal chakki for pretreated pulses. Their mill consisted of two 15 cm diameter cast steel disks. One is stationery and the other is rotates within an 18 cm diameter housing. The grain was passed in between the plates by adjusting the gap between them. Dehulling and splitting was accomplished by the shear and frictional action on the grain, which took place between the stationery and rotating disks. The hull and the fine powdery materials were separated from the dhal by a cyclone separator. Anonymous (2003) described a method for dehulling chickpea grain for dhal making use of a roller type dehuller. The process improved the recovery and quality of dhal. In order to substitute the traditional village level processing, CFTRI has developed an integrated small scale pulse processing unit- mini dhal mill. This consisted of a dehusking unit, aspirator and a reciprocating sieve, all run by a one horse power motor (Annual report, 1990, CFTRI).

Materials and Methods

Construction of the Dehuller

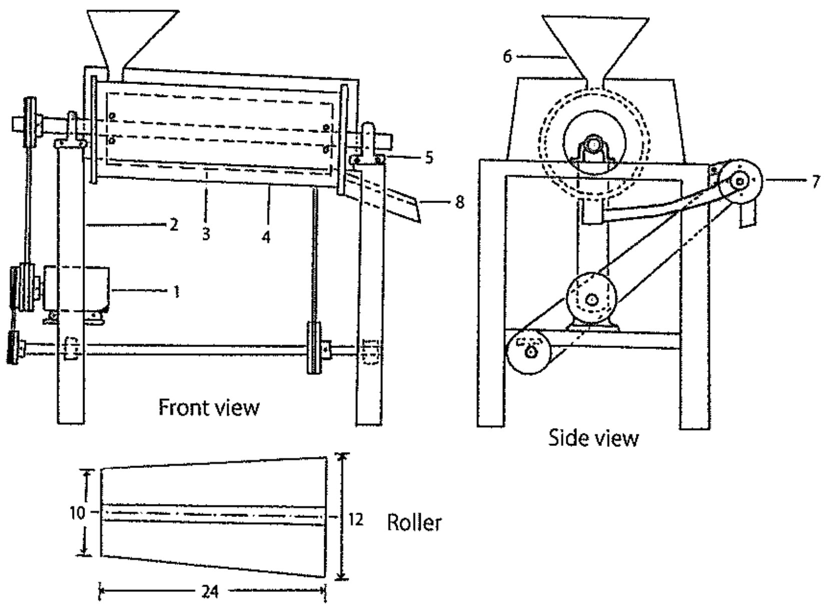
An abrasive roller type small capacity chickpea dehuller was developed at CRIDA. The main part of the dehuller consisted of an abrasive coated truncated cone roller (30 to 25 cm diameter, 60 cm length) and a concentric mesh drum, which was made from 1.5 mm thick, 2 mm diameter mesh holes mild steel sheet rolled into a cylinder. To develop the roller, two 2.5 cm thick, 27.5 and 22.5 cm diameter cast iron plates were selected and joined together using 1 cm uniform thickness and 60 cm length, good quality wooden flats to form a cylinder structure. To ensue a proper rough surface over the cylinder, medium grit size B-type carborundum abrasive material was plastered uniformly over the wooden surface to a thickness of 1.5 cm (**Fig. 2**). This abrasive surface was durable and easy to repair in case of wear during operation. The annular space between the mild steel drum and abrasive roller was kept at 1.5 cm. In operation, the abrasive surface inter-locked with the grain mass forcing grain to move along the peripheral surface of the roller; but the movement was restricted by the surrounding grain layer, which was confined by the stationery drum surface. As a result, the abrasive action; grain against grain, grain against abrasive roller surface and grain against drum surface was created, thus, increasing the dehulling efficiency.

The drum was fixed to a 95 × 64 cm rectangular frame made of 75 mm angle iron. A drive shaft 50 mm in diameter ran through the axis of the drum carrying the abrasive roller bolted on each side of the shaft (**Fig. 1**). The drive shaft was mounted on pedestal bearings and fitted to a pulley driven through a V-belt by a 3-horsepower electric motor. For loading and unloading of the grain in the machine, an inlet hopper was provided on upper top-side of the drum and an outlet at the lower end of the drum cover plate. The dhal delivered at the outlet by the dehuller contained considerable amount of husk. To separate these hulls, an aspirator containing four numbers of 75 × 62 mm size blades inside, was fitted to the machine. The product outlet duct of the dehuller was connected to the aspirator through a 5.5 cm diameter flexible hose pipe. The fan was driven from an auxiliary 2.5 cm diameter shaft, which was driven by the motor through a V-belt and pulley.

Grain Pretreatment Procedure

As shown in **Fig. 2** in the present study the cleaned grain was passed through the roller machine with lighter force, which caused a mild abrasion (tempering operation). This tempering caused slight scratches on the seeds and enhances their water absorbing efficiency, leading to the loosening of the seed coat. The grain material was then treated with

Fig. 1 Chickpea dehuller



1: Motor with plat form, 2: Main frame, 3: Abrasive roller, 4: Enclosed mesh drum, 5: Pedestal with bearing, 6: Grain hopper, 7: Suction fan, 8: Outlet water and heaped for a period of 4 hours to allow the surface moisture to be absorbed into the grain (conditioning). The conditioned material was spread on the drying floor to dry under the sun. If necessary the material was stirred occasionally. After sun drying, the grain was fed into the dehuller (**Fig. 3**).

Milling Tests

The chickpea grain produced in the local village was used to prepare the pretreated samples for the milling tests under a frontline demonstration of improved machinery for pulse crop production programme. The initial moisture content of the grain was 9 percent (dry basis). Moisture content of the cleaned grain was determined using a digital moisture meter. Thousand-grain weight was measured using an electronic balance. Dimensions of 50 grains were measured using a dial gauge type grain vernier. The shape of the grain was expressed in terms of sphericity calculated by the following expression.

$$\text{Sphericity} = \frac{\text{Geometric mean diameter}}{\text{Major diameter}}$$

In which, Geometric mean diameter = $(L \times W \times T)^{1/3}$ mm

Where,

L = Length, mm

B = Breadth, mm

T = Thickness, mm

Bulk density was measured by weighing the sample of known volume. The theoretical hull content of the grain was measured, by removing the husk of 100 g sample manually using sharp nails.

The milling tests were conducted with the newly developed dehuller using carefully treated samples. In each treatment, four replications were made and a 25 kg grain sample was used for each replication. The abrasive roller speed was nearly 900 revolutions per minute, which was found optimum in preliminary tests. The following four treatments were selected for the study.

T_1 = Raw grain milling

T_2 = Soaking of raw grain in water for 5 hours and 24 hours sun drying

T_3 = Raw grain milling to obtain splits + Edible oil application at 0.3 % for 48 hours and 24 hours Sun drying + Milling

T_4 = Tempering + Water application at 10 % for 4 hours and 8 hours sun drying followed by milling

The milled fractions were separated using a mechanical sieve set. The dehulling index and dhal recovery were calculated by the expressions,

$$\text{Dehulling Index} = \frac{(M_c + M_h) - (M_{uh} + M_f)}{M_t}$$

Where,

M_c = Mass of cotyledons and broken cotyledons

M_h = Mass of removed hulls

M_{uh} = Mass of grain that remained unhulled

M_f = Mass of fines in the final product

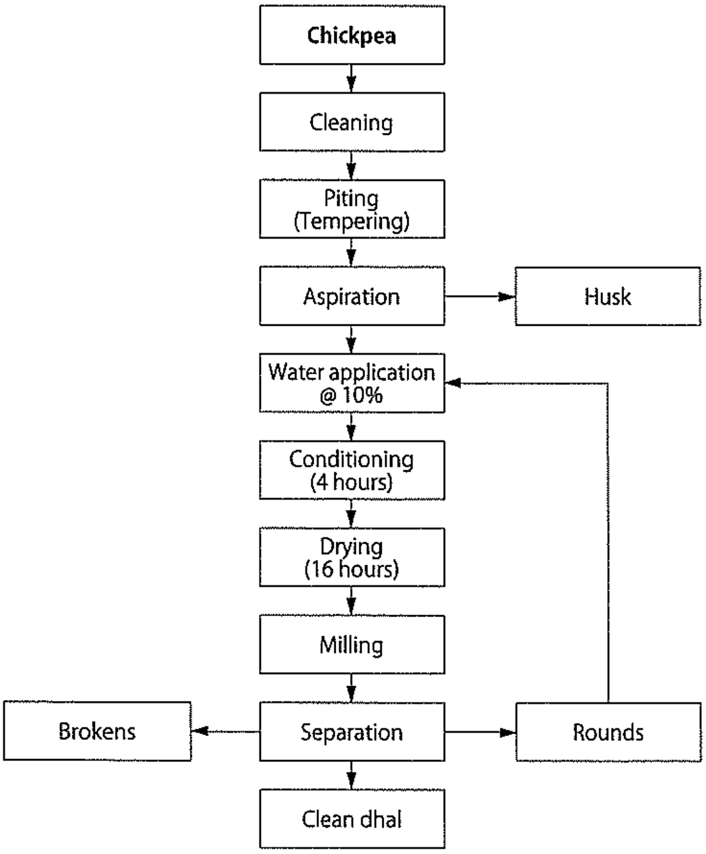
M_t = Total mass of sample fed into the dehuller

$$\text{Dhal recovery} = \frac{F_p}{M_t} \times 100$$

Where,

F_p = Mass of dehulled cotyledons and dehulled grain

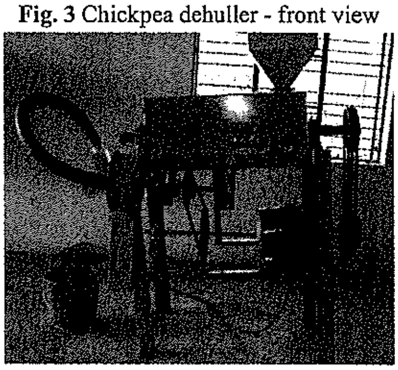
Fig. 2 Pretreatment process of chickpea



Results and Discussion

Table 1 shows the important

Fig. 3 Chickpea dehuller - front view



physical properties of chickpea grain used in the milling tests. The knowledge of geometric mean diameter and sphericity helped in deciding the clearance between two abrasive surfaces for dehusking and splitting. It will also help in designing the cleaner and separator. Gravimetric properties such as bulk density and thousand grain weights are necessary in design and analysis of separation, design of hoppers and blowers, which are essential parts of a dhal milling equipment.

The results of the analysis of variance for the brokens, dhal recovery and dehulling index calculated during the milling tests are shown in **Table 2**. The F value was significant at 1 percent level of probability for brokens, dhal recovery and dehulling index for all the treatments. This indicates that each treatment performed differently while dehulling. The performance results of brokens, dhal recovery and dehulling index obtained in all the four treatments is shown in **Fig. 4**. The treatment T_4 recorded the highest dal recovery of 78.3 percent and lowest broken (4 percent), where as, treatment T3 registered the height broken of 11.25 percent with 66 percent dhal recovery. In treatment T_2, the dehulling index was highest 0.95; slightly higher than T_4. This could be explained by the fact that soaking of the grain in water for a longer period usually caused cotyledons to swell and subsequent drying shrink the cotyledons by pulling away from the gummy layer (reduces tightness of the husk over the cotyledons) making it easy to remove husk during the milling process. In soaked grain, due to drying, the absorbed moisture defused out slowly leaving a considerable hollow space between the cotyledons. Consequently, the cotyledons became cup shaped from the original semi spherical shape. During milling the edges were broken away, increasing broken percent and powdering losses in milling. As a result, the over all dhal recovery was reduced to 70 percent, even though highest dehulling index of 0.95 was recorded (**Table 3**). The dhal obtained in the treatment T_2 was considered to be inferior in quality by the farmers and traders. Since there were no other options, farmers were resorting to this practice, which was more amenable to conventional milling units.

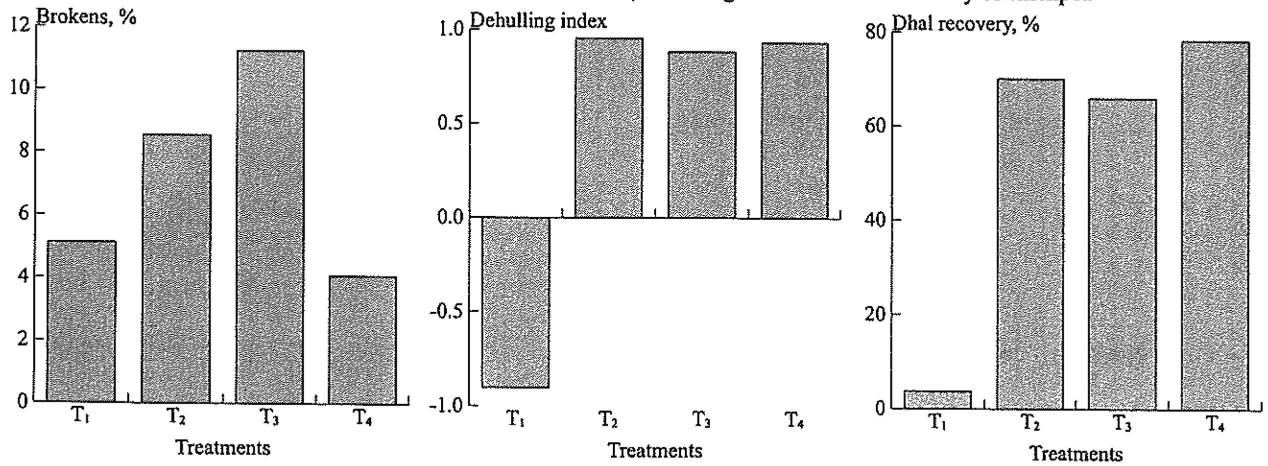
Comparison of the results obtained with the dehuller in treatment T_3, in which the chickpea was first split using a huller, then treated with oil and finally fed to the machine to remove the seed coat, showed that the prototype was able to achieve an improvement in dhal recovery of approximately 9 percent when compared with traditional small scale units of 57 percent mean recovery (Singh and Jambunathan, 1990) for the same treatment. This indicated that the prototype was more efficient than the traditional processing unit in splitting the grain kernels during the milling and dehulling. The index is more or less equal to that obtained in the traditional process.

Study of the results obtained with the untreated grain (T_1) showed that, the prototype was not able to achieve dehulling efficiently, i.e. most of the hull fraction remained with the splits, hence the dehulling

Table 1 Physical properties of chickpea used in the study

Sl No.	Length, mm	Breadth, mm	Thickness, mm	Size, mm	Sphere-city, mm	Bulk density, g/cm^3	1000 grain weight, g	Husk content, %
1	8.57	6.24	5.96	6.83	0.81	0.76	191.02	13.50
2	8.69	6.32	6.05	6.93	0.80	0.79	185.00	12.80
3	8.32	6.15	5.51	6.56	0.78	0.73	199.05	15.00
4	9.06	6.79	6.37	7.31	0.82	0.75	193.90	14.00
5	8.96	6.80	6.20	7.23	0.80	0.78	190.50	12.20
Mean	8.72	6.46	6.018	6.972	0.802	0.762	191.89	13.50
SDm	0.298	0.3117	0.3238	0.3051	0.0148	0.0238	5.135	1.081

Fig. 4 Effect of different treatments on brokens, dehulling index and dhal recovery of chickpea



index was found to be negative. The over all results obtained in these experiment indicated that there was a substantial improvement of the dehulling index by milling tempered and conditioned grain (T_4) using the prototype compared to dehulling of T_2 and T_3 treatments which were conventionally used. The dhal recovery levels from the prototype dehuller were also substantially higher compared to conventional milling units. In addition, the yields obtained were comparable with large scale commercial milling units where the yields varies between 70-80 percent (Singh and Jambunathan, 1990).

Conclusions

A small capacity prototype dehuller for pretreated chickpea incorporating basic principles from both traditional and mechanical dehulling systems was developed. The performance of the prototype was evaluated using four treatments consisting of both traditional and improved pretreatment methods. The grain scratched and moistened to 18 percent moisture content for 4 hours followed by sun drying16 hours yielded a dehulling index of 0.93. This indicated that most of the grain was fractionated into hulls and cotyledons. The dehulling index of the unconditioned control sample was -0.90 indicating that most of the grain sample was either broken or remained unhulled.

Comparison of the results obtained from the conventional treatments revealed that an average of 9 and 13 percent improvement in dhal recovery was achieved using the abrasive dehuller. The over all results indicated that it was possible to obtain higher recovery levels and higher dehulling index with the newly developed prototype dehuller than conventional milling units.

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Table 2 Analysis of variance for brokens, dehulling index and dhal recovery

Source	df	SS	MS	F
Brokens				
Replications	3	7.755	2.585	
Treatments	3	129.145	43.048	7.03**
Error	9	55.140	6.127	
Total	15	192.040		
Dehulling index				
Replications	3	0.008	0.003	
Treatments	3	10.012	3.337	2,280.68**
Error	9	0.013	0.001	
Total	15	10.033		
Dhal recovery				
Replications	3	75.563	25.188	
Treatments	3	14,087.810	4,695.938	270.81**
Error	9	156.063	17.340	
Total	15	14,319.440		

** = Significant at 1 % level

Table 3 Table of means for brokens, dehulling index and dhal recovery

Sl. No.	Item	T_1	T_2	T_3	T_4	Mean
1	Rank	3	2	1	4	
	Brokens, %	5.125	8.550	11.250	4.075	7.250
2	Rank	1	4	2	3	
	Dehulling index	-0.903	0.955	0.883	0.933	0.467
3	Rank	1	3	2	4	
	Dhal recovery, %	3.75	70.125	66.00	78.375	54.562

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Indigenous Rainguage (*Rolu*)- A Tool to measure Rainfall

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ABSTRACT : Indigenous rainguage (*Rolu*) (IR) is one of the Indigenous technical knowledge, which helped the farmers in quantifying rainfall approximately for farm operations. It is a mortar made of granite with a hole of 22.5 cm f and 2000 ml capacity. Depending upon the depth of water received in the hole of IR, the amount of rainfall received can be known and farm operations can be carried out. To standardize IR, validation of IR was done in three on-farm conditions and two research farms of CRIDA, Rangareddy district, Andhra Pradesh for three years and a correction factor was derived as 0.48. Some refinements were also carried out during this process like making a barrier surrounding the hole and creating an outward slope on the periphery of IR to avoid overflow, splash and human interferences. It is concluded that when the IR is >1/2 to full, all the farmers (100%) are proceeding to sow crops like sorghum +pigeonpea and castor for 2-7 days and 3-6 days respectively. If the rain is filled to ¼th to ½ of the volume of the hole, they are carrying the operation of sowing for 1-2 days. Intercultural operations like weeding, topdressing were carried out for 2-4 days when IR is filled to >1/2 to 3/4th depth and about 6-8 days when IR is >3/4th to full depth.

Key words: Indigenous rainguage, Standard rainguage, correction factor, ITK

Sustainable production of crops in rainfed areas depends on conservation and efficient utilization of natural resources. Being resource poor, farmers have not been able to adopt many of the improved technologies emerging from the formal research system. Some of the reasons are high cost, lack of replicability and technologies not matching with resources and socio-economic environment of farmers. It is very important to characterize the traditional knowledge systems and integrate with the modern methods of production so that high production with sustainability is achieved. ITKs are designed to address the process of building harmonious relationship among man, animal and nature. These are time tested based on local resource experiences turning into practices (Das and Das, 2000). It is dynamic, holistic, integrated with religion and puts greater weightage on minimizing risks rather than maximizing profit (Warren, 1990). It is a tacit knowledge, which is not easily modifiable and can be transmitted orally, imitation and demonstration. It is an experience rather than a theoretical knowledge and adaptive skills of local people and often flow through overall traditions and learned through family members over generations. It is the knowledge being produced as well as reproduced, discovered as well as lost. Indigenous knowledge refers to the unique, traditional, local knowledge existing within and developed around the specific conditions of women and men indigenous to a particular geographic area (Gremier Louise 1998). Documentation and validation of Indigenous knowledge is required to qualify and quantify the effectiveness of the practice for the benefit of researchers, planners and development officials. Suitable modifications of the local practices, through research and development will help to develop appropriate and acceptable technologies that are more suited to our farming situations.

Rainfed agriculture is beset with the problems of poor soils, ill distributed and low quantity of rainfall and it is imperative that timely sowing has utmost priority as the crop growth period is interspersed with the intermittent dry spells. Delayed sowing generally leads to experiencing intermittent dry spells during the crop period affecting the yield. Therefore, most of the farm advisory services are generally based on the rainfall received during crop period. These services can make use of the standard rainguages certified by India Meteorological Department, Pune. However, due to the area involved in big farms and watersheds, it is difficult to establish many rainguages that are theft prone. Therefore, an Indigenous rainguage (*Rolu*), which was documented, is validated and refined as an alternative to certain extent to the standard rainguage. This will generate an approximate estimate of the rainfall quantity received.

Materials and Methods

Indigenous Rainguage (Rolu)

The watershed areas, which are spread over many hectares, need to be monitored according to the rainfall received and distributed. There are standardized rainguages certified by IMD, Pune available. However, it is appropriate to fabricate an alternative rainguage, which can measure approximate quantity of rainfall, besides being inexpensive and theft proof. As a consequence of documentation of ITKs, we came across a mortar (*Rolu*) to measure rainwater. It is one of the Indigenous Technical Knowledge, which helps the farmers in estimating the rainfall whether it is sufficient to go for seeding, or not. This ITK was collected from the farmer of Nallavelli village, Yacharam Mandal, Ranga Reddy district of Andhra Pradesh, India. The predominant soil type of this area is *Alfisol* and the principal crops are Sorghum + pigeonpea and castor.

Rolu (Fig. 1) is a 22.5 cm ϕ hole in a granite stone block, which is useful in knowing the quantity of rainfall received for sowing. When the *Rolu* is filled with rainwater either with continuous rain events or a through a single rain event, then farmers go for sowing of seeds for 3-6 days. This method is adopted for sowing dryland crops like sorghum, castor *etc*., in *Alfisols*.

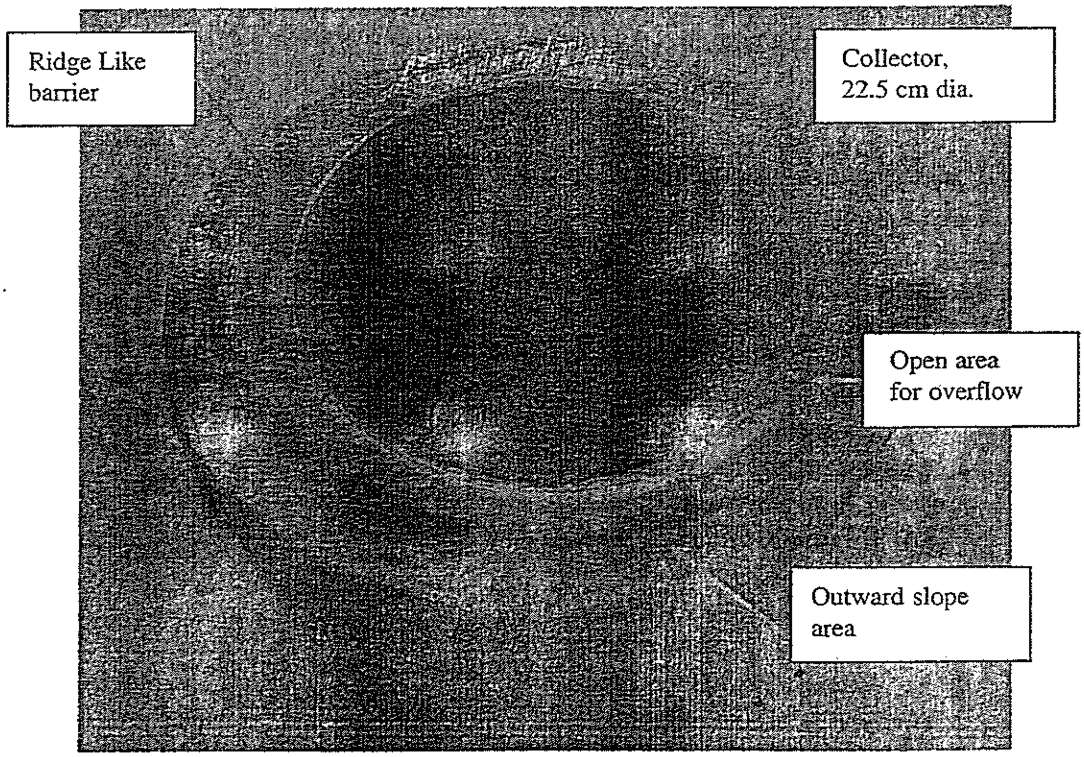

Fig 1. Indigenous rainguage

Origin:

This might have originated from the age-old practice of keeping mortar in the open space as the kitchens are built separate from the main building. Whenever there used to be rainfall, it was regularly observed over time that once the mortar is filled with rain water, they were sowing the fields for about 3-6 days during sowing month / with the onset of monsoon. In course of time, people started framing it as an indicator to approximate the quantity of rainfall received.

Procedure for validation of Indigenous rainguage

There are no standard packages to validate ITKs. Some are need to be validated at laboratory level, some at field level and some at both levels. The materials used in this experimentation are Indigenous rainguage made up of granite, Standard rainguage (SR), scale to measure the depth of rainwater in the hole and everyday monitoring of the sowing operations in the nearby fields (book keeping of farm operations in the nearby fields).

Discussion with the ITK discloser and fabrication of indigenous rainguage and Validation

Interacted with the discloser (farmer) to consider the finer details regarding Indigenous rainguage and its use. Rain gauges were fabricated with the help of a local mason with the specifications recorded as claimed by the disclosure. It has been standardized to a hole of 22.5 cm and 2000 ml capacity.

Validation was implemented under both on station (CRIDA Research Farms- Gunegal and Hayathnagar Research Farms) and on-farm situations (three villages) in the Ranga Reddy district of Andhra Pradesh, India for three years during 2002-2004. During *kharif* season, 2002 indigenous rainguages were installed nearby the standard rainguage to compare its efficiency in terms of recording rainfall related to the cultivation of rainfed crops of Sorghum + pigeonpea, castor *etc*., and sowing operation performed by different farmers in study area. The data on rainfall and the farm operations related to crops were documented in both the standard and indigenous raingusges. Further, the quantity of rainfall received in both indigenous and standard rainguages from June to September was correlated by taking the volume of water stored in two rainguages, considering the surface area, collected rainfall in each. Based on above parameters, a correction factor was calculated to correlate the quantity of rainfall received in IR with that of SR.

Determination of correction factor

The rainfall depths were calculated by measuring their corresponding volume of rainfall collected by the respective raingauges by using the equation:

$$R = (V_m/A_s) \times 10 \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where,

R = Rainfall depth, mm
V_m = Measured volume of rainfall, ml
A_s = Surface area of respective rainguage, cm^2

A linear regression model as given below is considered in the analysis for deriving the correction factor (C_f) for relating the rainfall measured by IR and SR.

$$R_s = C_f \times R_i \quad \ldots\ldots\ldots \quad (2)$$

Where,

R_s = Rainfall depth measured by SR, mm
R_i = Rainfall depth measured by IR, mm

The loss of rainwater in the form of overflow, splash and human interferences were recorded. An outward slope is also provided to avoid overflow from the rainfall collecting area.

Results

Standardization of IR

After series of discussions and interactions of our team including the agro meteorologists with the farmers and the manson, the existing IR was standardized for accuracy in the measurement of rainfall as given below:

- Making a ridge like barrier surrounding the hole leaving the path for water to pass through one side maintaining same volume of rainwater as that of original IR;
- By creating an outward slope on the periphery of the indigenous rainguage to account for splash and human interferences etc.

Correction factor

The rainfall volume from both IR and SR established at different experimental sites was recorded. Simultaneously, the various agricultural operations done by the farmers were related with the rainfall received during sowing of different crops of sorghum+pigeonpea, castor *etc.* A linear regression model was fit into the rainfall depths calculated from both IR and SR. During the process, a correction factor was developed to quantify the rainfall of indigenous (IR) to test the validity of rainfall with that of standard (SR). The results are validated over the study area by developing a correction factor for its wide applicability by comparing with the theoretical correction factor. The collecting surface areas of IR and SR are 200 and 398 cm^2. C_f obtained was 0.48 when the linear model was validated with the rainfall data measured from the experimental sites, with high coefficient of determination($R^2 = 0.92$). The value of correction factor is as equal as theoretical correction factor of 0.5 which is the ratio of surface area of collecting rainfall of both IR and SR. Hence, for all practical purposes, the rainfall measured through IR could be converted into rainfall depths of SR, which is very useful for scientific planning of crops and their management practices in the farmer's field. Since the variability of rainfall in semi arid regions is very high, the correction factors have to be developed locally by installing IR and SR.

Correlation of rainfall from IR with reference to the rainfall recorded by the SR for carrying out Sowing and other farm operations

The quantity of rainfall from IR has been related with the sowing operation carried out by the farmers of the surrounding fields by recording the percent farmers sown with the rain events. This is presented in Table 1. Village wise on farm operations were recorded and presented below:

Table 1. Sowing operation being carried out in relation to the rainfall received in the IR (pooled data of 3 years for 3 on-farm stations and two Research stations)

Crop	Duration of operation (days)	Depth of water in IR	Percent farmers adopted
Sorghum+ pigeonpea	2-7	>½ to full	100
Castor	1-2	¼ to ½	100
	3-6	¾ to full	100

Nallavelli

The initial rains of 10 mm (R_i >1/4 full was utilized for preparatory cultivation and the next rains (3/4 full) was utilized for sowing Sorghum+pigeonpea which is 100% in this village. Similar rain received later was utilized for the interculture and top dressing. However, the crop was immediately harvested with an yield of 3.5-5 q ha^{-1}. Castor being a late sown crop is sown always with the next rains (Table 2).

Nasdiksingaram

All sorghum farmers had sown the crop when they received >1/2 to full depth rain in IR in all the years. When similar quantity of rainfall was received during July, two days were for tillage to sow castor and sowings were done for the next three days after receipt of rainfall (Table 2).

Gollapally

Castor is the major crop in this area and generally it is sown in July as and when the rains received are ½ to ¾ full (cumulative rainfall). It helps the farmers in getting good germination of castor seed in the fields as they are hard coated (Table 3). Depending upon the time of onset of monsoon/ rainevent, the sowings of Sorghum+ pigeonpea was done by all the farmers within 2-7 days when the IR is >½ to full while for castor, when the IR is ¾ to full, all the farmers had sown within 3-6 days.

Overflow events

33 years rainfall of Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad was analysed (Table 5) for overflow events (1971-2003). The overflowing rainfall events depend on the amount of rainfall received and its distribution in the respective months. The probability of receiving overflowing rain events ranged from 10-28%. Though the probability of receiving overflowing rainfall events is less, the refinement in terms of reducing the diameter/ collection area, retaining the capacity (volume) of the IR will reduce the overflow. Therefore, the confidence of recording the rainfall events with this IR will improve by not losing even a single overflow event.

Discussion

The experimentation in three villages and two research stations proved that when the IR is > ½ to full, the farmers proceeded to sow sorghum + pigeonpea for 2-7 days and castor for about 3-6 days. However, if it were less, sowing for 1-2 days would be carried out. If it were still delayed, only castor crop would be sown. Correction factor of 0.48 is used to arrive at the rainfall of SR by multiplying the rainfall recorded in IR with C_f. Refinement to suit different locations can be carried out keeping the surface area narrow without affecting the capacity for its wider applicability, for overflow events observed in that area and for losses due to splash and human interference. Farm advisory by the NGO's or any other organizations can be given based upon the volume of rain that is received within the IR even in remote areas. IR costs around Rs. 250-300/unit as against the cost of SR for Rs. 3000-3500/ unit in the market. IR has multiple utilities of recording as well as in preparation of various food products for consumption. The IR would help in accurate measurement of rainfall in remote areas, where to install SR is a remote possibility because of theft problems.

Table 2. Effect of rainfall received (Std(SR) and indigenous rainguages) (IR) on duration of agricultural operations carried out in Sorghum+ppea and Castor crops

Operation	2002					2003					2004				
	Rainfall (mm)		Duration of operation (days)	Farmers practiced (%)		Rainfall (mm)		Duration of operation (days)	Farmers practiced (%)		Rainfall (mm)		Duration of operation (days)	Farmers practiced (%)	
	SR	IR		S + PP	castor	SR	IR		S + PP	Castor	SR	IR		S + PP	Castor
Nallavelli															
Sowing	8 (1)	28	4	100	-	32.8 (1)	95.4- **>3/4**	6	100	100	20(1)	40- **>1/2**	2	100	1
Interculture	1 (1)	2.4 -**<1/4**	2	50	60	2.8(1)	5.8	3	90	-	24(1)	46 **>1/2**	4	100	100
&Top dressing	14.2(2)		4	50	35	32.6 (4)	88.2- **>3/4**	5	-	100					
Sowing		38.4 – **>1/2**													
Nasdik singaram															
Sowing	25.2 (1)	-	11	100	-	8 (1)	36- **>3/4**	3	100	100	19.5(1)	41.2- **>1/2**	2	100	-
Interculture and Top	24.1 (4)	80- **>3/4**	6	75	50	44.4(2)	129- **full**	8	100	50	20.3(3)	59.3-**3/4**	4	80	100
dressing						14.5(4)									
Sowing							33.1- **>1/2**	1	-	50	35.2(1)	93.2- **>3/4**	1	20	-

Figures in parenthesis are number of rainevents; figures in italics and bold are the depth of hole filled with rainwater
S : Sorghum , P P : Pigeonpea

Table 3. Effect of rainfall received (Std (SR) and indigenous rainguages) (IR) on duration of agricultural operations carried out in Castor crop in Gollapalli

Operation	2002					2003					2004				
	Rainfall (mm)		Duration of operation (days)	Farmers practiced (%)		Rainfall (mm)		Duration of operation (days)	Farmers practiced (%)		Rainfall (mm)		Duration of operation (days)	Farmers practiced (%)	
	SR	IR		Sorg hum +ppea	Castor	SR	IR		Sorg hum +ppea	Castor	SR	IR		Sorg hum +ppea	castor
Sowing	7(2)	-	2	-	50	18(2)	38- **>1/2**	3	-	100	7(2)	19.5- **>1/4**	3	1	100
Interculture & Top dressing& Sowing	27(2)	33-**>1/2**	4	-	30	39(20)	96- **full**	2	-	50	34.3 (4)	66- **>3/4**	6	-	50
													4		50
											6.3 **(3)**	17- **>1/4**			

Figures in parenthesis are number of rainevents; figures in italics and bold are the depth of hole filled with rainwater

Table 4. Probability (%) of receiving overflowing rain events in HRF of CRIDA, Hyderabad as per IR (> 50 mm) (Data: 33 years)

Month	Total rainy days	Overflow events (>50 mm)	Probability (%)
January	15	3	20.0
February	18	4	22.2
March	21	5	23.8
April	52	5	9.6
May	86	15	17.4
June	213	43	20.2
July	300	64	21.3
August	295	70	23.7
September	247	65	26.3
October	189	52	27.5
November	66	13	19.7
December	14	3	21.4
Total	**1516**	**337**	**22.2**

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Management of *Celosia argentea* L. in Non-cropped Lands in Alfisols

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ABSTRACT: Weed control is an activity proved to be labour intensive than any other activity in crop production. Weed composition and management is solely dependant on the persistence of weeds in soil. *Celosia argentia* (L.) is one of the most persistent weeds with faulty management. By applying different management techniques before they come to flowering, it is possible to control it since it is a seed propagated weed. Hence, an experiment was conducted by using the implements like Garden sword and hedge cutter to cut them back before they come to flowering. However, the growth pattern and reproductive stages were observed in order to assess the effectiveness of the management practice. Regrowth was observed with 2-3 days after cutting back irrespective of the height at which they were cut. All plants have come to flowering at the same time indicating its season bound nature. Further, all the inflorescences put on by the plant after the cut back were small (5 cm in length) and did not produce any seed. This practice may be practically feasible in non-cropped lands since it not only helps in controlling the seed production but also adds green matter to the soil. In due course of time, the weed seeds deposition gets reduced leading to less weed number and improved soil fertility.

Key words: Non-cropped lands, Regeneration, *Celosia argentia* (L.)

Prudent weed management is an important economic proposition for farm management. Farm manager has to take an important decision of proceeding with the varied approaches like chemical and non-chemical, cultural and mechanical. Because of the germination delaying factors as the dormancy-non-dormancy continuum (Baskin and Baskin, 1985), seeds of annual species can persist in soil for years, resulting in a reservoir of viable seeds of various ages from which future generations develop. Mostly the weed problem faced by the farm managers might be due to the continuous negligence of weeds in non-cropped areas, which increase the weed seed bank in the soil of cropped areas. The persistence of weed seeds in the non-cropped areas would cause infestation of croplands due to mismanagement through the implements (Hoffman et al. 1998). As per Zimdahl (1980), weed species present in a disturbed (cropped) community are a secondary effect of weed management. Intensive cropping systems give rise to weed communities that are products of not only the cropping pattern and weed management system but also the result of faulty management of non-cropped lands as well. Hence, the understanding of weed ecology and weed biology and agronomic practices to manipulate these factors to obtain better weed management and more crop productivity is essential. *Celosia argentea* L. is considered one among such weeds. If mismanaged, it leads to an enormous problem due to its persistence, as it is a prolific seed producer. One of the weed management strategies is to control these weeds before they come to flowering. Hence, a study has been planned and conducted in the non-cropped lands following the above strategy.

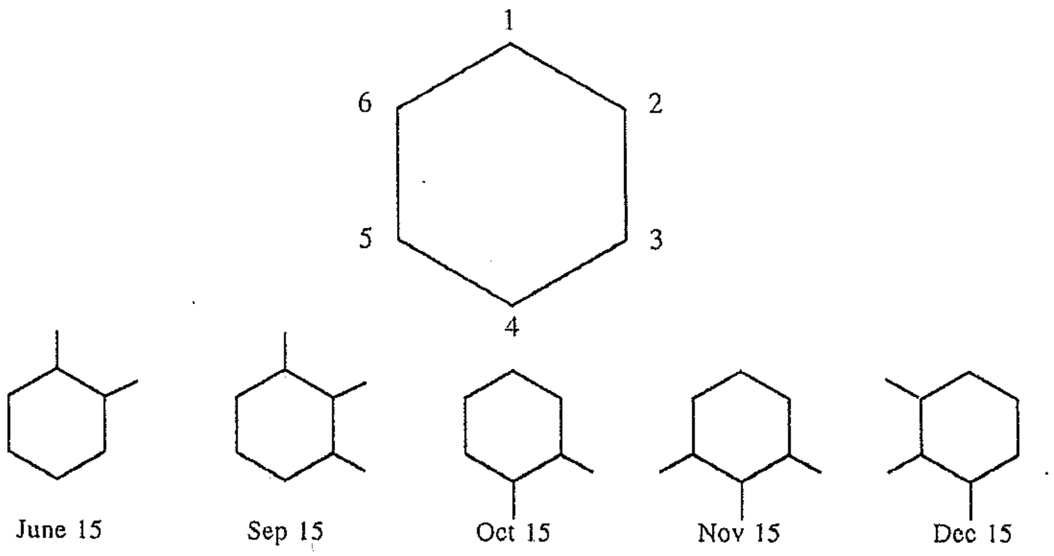
Weed ecology and biology

Before the experiment is planned, knowledge of weed biology and ecology are essential in order to organize the management practices. *Celosia argentea* L. is commonly known as Cock's comb, a common weed of dryland Alfisols of Telangana Region of Andhra Pradesh. The plants are usually annual herbs, with taproot system. Leaves are alternate, oblong, lanceolate. Inflorescence is dense, terminal spikes, elongate and pinkish white. Fruit two seeded utricle, dehiscent and black. It is an annual dicot weed propagating through only seed. Each plant produces around 300-500 seeds per season and the seeds are very small and black (Shetty, 1978). With the onset of the monsoon, seeds at the surface of the soil will germinate and these seedlings start dominating from August onwards and by the month of October and November, they come to seed setting and complete the life cycle (Figure 1).

Materials and Methods

A table representing the composition of different weeds and the dominance of *celosia* in the existing composition in the non-cropped lands is mentioned in Table 1. Garden sword and hedge cutter are the two different hand implements used in cutting back Celosia in non cropped lands. The principle of controlling these plants before flowering is to reduce the seed set and utilize the preanthesis green matter produced by the plant for the soil fertility.

The implements were used at different heights to slash off the celosia plants in order to observe the time required to cut back, its regrowth, time of attainment of the reproductive stage and the seed producing ability of the plant. In order to use garden sword, the plant needs to be grown up to a certain height of around 25-30 cm. However, the same is not the case with the hedge cutter. Different heights were taken into consideration while using the hedge cutter.



The hexagonal phenograms are depicted with positions 1-6, indicating the phenophases of the plant

1. Emergence, 2. Vegetative phase, 3. Flowering, 4. Fruiting, 5. Seed maturation and dispersal, 6. Death / disappearance

Fig. 1. Phenological stages of *Celosia argentia* (L.)

Table 1. Weed composition of non-cropped field in Alfisols of Telangana region (mean of three years data)

Time of sampling	Grasses		Sedges		Celosia		Total
	No. m^{-2}	%	No. m^{-2}	%	No. m^{-2}	%	No. m^{-2}
First fortnight of July	29.6	45.3	20.3	31.1	15.4	23.6	65.3
Second fortnight of July	44.25	8.8	190.5	37.9	268	53.3	502.75
First fortnight of August	23	7.9	97.6	33.1	174	59	294.9
Second fortnight of August	15.63	9.7	39.63	24.8	104.8	65.5	160.06
First fortnight of September	31	16.2	–	–	160.9	83.8	191.9

The heights of celosia were fixed at 20-25 cm and 40-60 cm. The average plot size was 2 x 5 m. The plot was infested with 125 plants of Celosia m^{-2} on an average. This was replicated thrice. The means of the parameters were considered for interpretation. Time take for the operation was noted and indicated in the Table 2. The stubble left in the field was measured and days for regeneration were noted down. The green matter added was collected and weighed and mentioned in g m^{-2}. The inflorescences developed after the cut back did not produce seed at all and they were termed as "infertile" in this experiment. The additional advantage is that the voluminous quantity of green matter generated was added to the soil both as mulch cum manure.

Results and Discussion

On an average, celosia was observed in 126 No. Per m^2 which is about 56% of the total weed composition and adds about 65-85 g m^{-2} depending upon the time and stage of sampling. Initially a little domination was observed with regard to grasses. However, this trend got reversed over time and Celosia started dominating the existing weed composition from end of July onwards. Of the total weed composition, Celosia constituted about 23.6% in the first fortnight of July extending to 83.8% by the end of the first fortnight of September. However, the number of sedges observed was almost same from the start of July to end of September (Table 1).

Table 2. Effect of cutting back of Celosia on regeneration and the green matter added to the soil

Hand tool used	Height of Celosia (cm)	Stubble height (cm)	Time taken for operation (min/10 m^2)	Green matter added (g/m^{-2})	Status of Inflorescences after cutting back	Days to regenerate
Garden Sword	30-35	10	5	75	No seed setting was observed in the regenerated inflorescences	2-3
Hedge cutter	40-50 (just before the the inflorescence was visible)	10	8	83		
Control (Hedge cutter)	50-60	40-45	5	45		
Hedge cutter	20-25	10	15	30		

Celosia was cut at different heights using the hand tools. The expected mean minimum height to be attained by the weed plant is around 20-35 cm, so that the use of hand tools is possible especially for the hedge cutter. The average stubble height left after the use of the hand tools in the field was around 10 cm. Since, Celosia is a seasonal weed, it is bound to complete its life cycle before the season comes to end. This has been reflected in the observations as all plants have come to flowering at the same time. The time taken to cut the celosia at different heights in a plot of 2 x 5 m was recorded. Garden sword took less time (5 minutes) for cutting compared to the hedge cutter. Further more, the hedge cutter when used for the plants at a height of 20-25 cm took longer time (15 minutes) and it decreased with increase in height of the plant (8 minutes). For control plot where the inflorescences were just initiated, it took only 5 minutes to cut. The inflorescences appeared after the cut back did not set the seed irrespective of the pruned heights. Hence, in addition to the hindrance created in seed setting, it is essential to utilize the voluminous biomass generated by the weed plant as well for recycling. On an average a single Celosia plant produces about 500 seeds and this practice reduces seed production and addition to the soil.

Some rituals and customs also are helping in containing the flowering and seed setting (Shetty and Krantz, 1980). For instance, a local festival-Bathukamma in Andhra Pradesh, coincides with the peak flowering stage. The inflorescence is extensively cut for decoration and thus seed setting of the first flowering is eliminated. This effectively helps to check the first seed setting on the plants.

Thus, it can be concluded through this experiment that this practice through weed biology management (Bantilan et al. 1974) is a trial to shift the balance in favour of crops. This may be practically feasible since it not only helps in controlling the seed setting but also adds green matter to the soil as mulch cum manure especially in non-cropped lands and bunds. In due course of time, the weed seeds deposition gets reduced leading to less weed number per unit area. All plants have come to flowering at the same time irrespective of the heights at which they were cut indicating its season bound nature. Further, all the inflorescences were small (5 cm in length) and seedless once they were cut back. Regrowth was observed within 2-3 days after cutting back.

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Drought Management Options for Rainfed Pigeonpea in *Alfisols*

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ABSTRACT : Field experiments were conducted during two *kharif* seasons in the year 1995-96 in *Alfisols* at Central research Institute for Dryland Agriculture, Hyderabad. The results indicated that medium duration pigeonpea (LRG-30) recorded higer yield by 70 percent than short duration pigeonpea (ICPL-87) in both rainfed and strees free environments. Among the management practices, stress free pigeonpea on an average, recorded 68 percent additional seed yield compared to rainfed environment. Supplemental irrigation of 5 cm at early (vegetative), mid (flowering) and terminal (pod formation) periods gave 31, 42 and 49 percent increased seed yield respectively over rainfed crop. Establishing a soil mulch through additional interculture practices at early and mid stress periods gave yield advantage to an extent of 12 and 19 per cent respectively compared to no soil mulch. Application of additional 10 kg N ha^{-1} after relieving the moisture stress at vegetative and flowering periods enhanced the seed yields of pigeonpea by 19 and 29 percent respectively compared to control. Thus, yields of rainfed pigeonpea in *Alfisols* can be stabilized to a certain extent through interculture (low monetary input) during early and mid moisture stress period and by additional nitrogen application (monetary input) after the relief of early and mid stress period.

Key words: Pigeonpea, supplemental irrigation, stressed and stress free situations

Moisture stress is a common recurring phenomenon in rainfed crops. The moisture stress during intermittent crop growth periods causes yield reduction and fluctuations in crop yields in rainfed environment, which can be minimized by selecting drought tolerant crops and varieties to match the growing season, screening of genotypes for drought tolerance and evolving appropriate agro-techniques for stabilizing yields (Subba Reddy *et al.*, 1996)

Pigeonpea is an important pulse crop grown widely as sole crop and intercropped in rainfed *Alfisols*. The reduction in yield of pigeonpea depends upon the degree and intensity of drought spell and also the stage of crop growth which the crop experiences. Hence, there is a need to study the various management options with different genotypes of pigeonpea for stabilizing monetary returns in rainfed situations

Materials and Methods

The experiment was carried out at Central Research Institute for Dryland Agriculture (CRIDA) farm during two *Kharif* seasons of 1995-96. The experimental site was sandy loam in texture, neutral in pH, low in available nitrogen (210 kg ha^{-1}). Pigeonpea varieties ICPL-87 and LRG-30 were sown during the second fortnight of June in rows 60cm apart in each season. The crop received 10 kg N and 30 kg $P_2O_5 ha^{-1}$ as basal dose and standard agronomic measures were adopted. The treatments comprising of management practices viz., additional interculture during moisture stress at vegetative (S1) and flowering stages (S2); additional nitrogen 10 kg N ha^{-1} after relief of moisture stress at both vegetative (S1) and flowering stages (S2) and supplemental irrigation of 5 cm during stress periods (S3) were evaluated in a randomized block design with three replications. The growth parameters viz., drymatter, leaf area index (LAI) yield and yield components such as pod bearing zone, contribution of nitrogen through leaf litter were estimated. Rainfall use efficiency (RUE) was also calculated (Jorge Elizondo-Barron, 1991).

Rainfall Pattern

The genotypes ICPL-87 and LRG-30 received about 500 and 738 mm of rainfall during their crop growth periods in first season respectively. The short duration

ICPL-87 underwent moisture stress for 12-15 days at vegetative, flowering and pod formation stages of crops, while medium duration pigeonpea (LRG-30) experienced intermittent dry spells of 12, 25 and 40 days in early (0-45 DAS), mid (45-90 DAS), mid (45-90 DAS) and terminal (90-120 DAS) growth stages. But the rainfall of 43 mm received in November helped to improve the grain filling in LRG-30.

In second season, ICPL-87 and LRG-30 received about 540 and 845 mm of rainfall during their respective growth periods. ICPL-87 experienced dry spells of 10 and 15 days during vegetative phase. Medium duration LRG-30 underwent moisture stress >14 days at vegetative phase, 15 days at flowering and >45 days at pod filling. However, the rainfall of 41 mm received on 8[th] November helped to get improved seed yields of LRG-30.

Results and Discussion

The medium duratin pigeonpea (LRG-30) recorded higher yield than short duration genotype (ICPL-87) in both rainfed and stressed environments. In rainfed systems, medium duration pigeonpea gave 70 and 62 percent higher seed yield than short duration genotype in first and second season respectively (Table 1). On an average, ICPL-87 and LRG-30 after harvest contributed 28 and 40 Kg N ha^{-1} to the soil through leaf litter in rainfed and stress free environments respectively (Table 2). Similar increment in stalk yields and gross returns were noticed in both the years.

During the first season, among the management practices, additional interculture during early and mid moisture stress gave higher seed yield of 42 and 89 Kg ha^{-1} respectively than no interculture in rainfed ICPL-87 (524 Kg ha^{-1}). Application of additional nitrogen @ 10 Kg N ha^{-1} after relief of early and mid stress periods gave additional seed yields of pigeonpea by 70 and 154 Kg ha^{-1} in rainfed conditions. The yield gains with additional interculture and additional nitrogen in both early and mid moisture periods was higher in medium duration genotype (LRG-30) compared to short duration genotype (ICPL-87). Supplementary irrigation of 5 cm during early, mid and terminal stress periods increased the seed yields by 199, 236 and 278 $Kgha^{-1}$ in ICPL-87 and 531, 576 and 720 Kg ha^{-1} in LRG-30 respectively over corresponding genotypes in rainfed environment (Table1).

Additional interculture during intermittent dry spells at vegetative phase (early moisture stress) increased the seed yield of LRG-30 and ICPL-877 by 3 and 7 per cent respectively over no additional interculture in second season. Increased seed yields of 9 and 13 percent were recorded with additional interculture during mid stress period (60-90 DAS) in LRG-30 and ICPL-87 respectively over control. Application of nitrogen @ 10 Kg N ha^{-1} after relief of moisture stress at vegetative and flowering periods gave higher seed yields in ICPL-87 by 14 and 24 per cent over rainfed environment. Supplementary irrigation of 5 cm each during moisture stress at vegetative (early), flowering (mid) and grain filling (terminal) stages recorded higher yield in ICPL-87 by 22,40 and 50 per cent respectively compared to stressed environment. In LRG-30, supplemental irrigation of 5 cm at vegetative, flowering and pod formation stages recorded increased yield benefit to the tune of 11, 22 and 28 per cent over control. Supplemental irrigation of 5 cm either at early or mid or terminal stages recorded the highest yield benefit in both the genotypes during both the years followed by the application of additional 10 Kg N after relief of early and mid moisture stress. Increased yield of pigeonpea genotypes due to varied management practices is attributed to efficient utilization of rainfall as evidenced by Rainfall Use Efficiency (RUE), (Table 2) and also yield components (pod bearing zone). The partitioning of photosynthates in realizing the yield is more in medium duration pigeonpea than short duration pigeonpea (Vijayalakshmi, 1983; Subba Reddy *et al.*, 1996, Oguneremi, 1996). Thus, the study indicated that moisture stress during flowering and grain formation stages are critical in influencing the yield of rainfed pigeonpea in short and medium duration genotypes under rainfed environment. The highest increase in pigeonpea yields with supplemental irrigation was due to higher compensation of drymatter production, better utilization of moisture through higher RUE and light after relief or stress periods. (AICRPDA, 1999). In both the years, maximum gross returns were obtained from the management practices such as additional interculture during early and mid moisture stress stages than without interculture in both medium (LRG-30) and short duration (ICPL-87) genotypes (Table 1). Gross returns from the crop with additional interculture, additional nitrogen in both early and mid moisture stress periods and supplementary irrigation of 5 cm during early, mid and terminal stress periods were higher in medium

Table 1. Effect of drought management practices on yield and gross return n rainfed pigeonpea

Treatments	Seed Yield (kg ha^{-1})				Stalk Yield (kg ha^{-1})				Gross returns (Rs. ha^{-1})			
	1995		1996		1995		1996		1995		1996	
	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30
1. Rainfed (Control)	254	959	842	1364	2512	4982	2778	5324	6288	11508	10104	16368
2. Addl. I.C. at S1	566	1272	899	1405	3068	5232	3125	5450	6792	15264	10786	16860
3. Addl. I.C. at S2	613	1325	950	1489	3162	5175	3048	5710	7356	15900	11400	17868
4. Addl. No. (10 kg/ha) after relief of stress at S1	594	1350	962	1469	3275	5319	3420	5625	7128	16200	1544	17628
5. Addl. N (10 kg/ha) after relief of stress at S2	678	1420	1085	1560	3462	5979	3520	6244	8136	17040	13020	18720
6. S.I. 5 cm at S1	723	1590	1024	1511	3612	6212	3472	6481	8676	19080	12288	18132
7. S.I. 5 cm at S2	760	1635	1180	1659	3860	6319	3612	6472	9120	19620	14160	19908
8. S.I. 5 cm at S3	802	1679	1260	1747	3691	6531	3472	6420	9624	20148	15120	20964
9. S.I. 5 cm at S1+S2+S3	1050	1980	1330	1825	3271	6970	3125	7060	12600	23760	15960	21900
C.D. (0.05)	161	303	113	96	756	989	896	1062	1250	1360	800	1050

S1 : Stress at vegetative stage: S2 Stress at flowering stage; S3 : Stress at grain formation stage
IC : Intercultural; S.I. : Supplemental irrigation

Table 2. Effect of drought management practices on rainfall use efficiency, N contribution and pod bearing in rainfed pigeonpea

Treatments	RUE (kg ha^{-1} mm^{-1})				N contribution through leaf litter (kg ha^{-1})				Pod bearing zone (cm/branch)			
	1995		1996		1995		1996		1995		1996	
	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30	ICPL-87	LRG-30
1. Rainfed (Control)	1.05	1.30	1.49	2.15	15.2	25.1	18.4	28.6	28.75	51.70	31.20	63.12
2. Addl. I.C. at S1	1.13	1.72	1.60	2.21	16.3	28.3	19.5	30.1	32.7	52.60	33.50	64.63
3. Addl. I.C. at S2	1.23	1.79	1.68	2.34	17.1	29.7	22.8	32.5	30.75	53.72	34.62	70.22
4. Addl. N at S1	1.19	1.83	1.70	2.31	18.3	32.5	21.7	36.6	31.92	54.92	33.90	67.27
5. Addl. N at S2	1.35	1.92	1.98	2.45	19.6	33.6	22.0	38.7	32.75	56.12	34.12	72.25
6. S.I. 5 cm at S1	1.45	2.15	1.61	2.38	20.1	34.7	23.6	42.6	34.92	58.12	35.72	66.69
7. S.I. 5 cm at S2	1.52	2.22	1.76	2.43	21.3	35.0	24.7	41.6	37.92	61.32	36.42	73.94
8. S.I. 5 cm at S3	1.60	2.28	2.20	2.54	20.1	30.1	22.2	38.2	39.75	62.75	37.39	73.00
9. S.I. 5 cm at S1+S2+S3	2.10	2.68	2.00	2.22	24.3	36.1	26.7	43.9	40. 72	65.92	39.42	77.00
C.D. (0.05)	0.56	0.62	0.38	NS	5.9	7.1	6.02	8.05	10.75	10.00	6.90	7.38

S1 : Stress at vegetative stage; S2 Stress at flowering stage; S3 : Stress at grain formation stage
IC : Intercultural; S.I. : Supplemental irrigation

duration genotype (LRG-30) than the short duration (ICPL-87) one in both years. Soil mulch through additional interculture registered additional gross income by 32 and 38 percent respectively over control during early and mid stress periods in medium duration pigeonpea by conserving moisture (AICRPDA, 2000).

It can be concluded from this study that the yields of rainfed pigeonpea in *Alfisols* can be stabilized by 15-30 per cent through extra interculture (low monetary input) or extra nitrogen application (monetary input) after relief of early stress.

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