DEVELOPMENT AND PERFORMANCE EVALUATION OF RICE-FALLOW PULSE PLANTER FOR WETLAND RICE ECOSYSTEM

[1]ARUMAIRAJ VEERAMANI, [2]PADMANATHAN.P.K, [3]PANDI PREMA, [4]SRIDHAR.N

[1]Agricultural College and Research Institute, Kudumiyanmalai-622 104, TamilNadu, India;
[2,4]Agriucultural Engineering College and Research Institute, Kumulur-621 712, TamilNadu;
[3]Agricultural College and Research Institute, Madurai-625 104, TamilNadu
E-mail: [1]veeramanitnau@gmail.com, [2]pathuphd@gmail.com, [3]pprema23@gmail.com, [4]n.sribtech@yahoo.com

Abstract- In wetland rice ecosystem, sowing of pulse either blackgram or greengram is generally performed either by broadcasting seeds manually in standing crop of rice fields at 7 to 10 days before harvest or dibbling manually immediately after rice harvest as traditional practices, a low cost technology which involves only sowing and seed cost. Nonetheless, these practices causes constraints like uneven distribution of seeds at shallow depth in broadcasting method and randomly placed seeds with improper depth and loss of moisture in manual dibbling after rice harvest which in-turn leads to poor contact between seeds and soil, low germination, more weed growth, unhealthy plants and lower yield. Of the field conditions followed, sowing in the standing crop condition at 7-10 days before rice harvest has advantage of more moisture content rather after harvesting rice at which residual moisture content is less. However, for effective utilization of residual moisture besides other resources like light, space and nutrients, placing seeds at proper spacing and at optimum depths is a must so as to better growth and development and yield of crop. As sowing seeds at proper spacing by manual means in standing crop condition is technically not feasible and economically unviable, machine sowing would offer a coping mechanism to accomplish the situation. Being a challenging task, a "Rice-fallow pulse planter" was designed and developed in such a way that it sow rice fallow pulse at proper spacing of 25x10cm with optimum depths of 3-4cm in line sown standing rice crop fields in wetland rice ecosystem with no or negligible damage. The machine has two large tread M.S wheels each having 1760mm dia with six spokes joining at hub mounted over bearing positioned at center of the wheel. These wheels were mounted on the mid-point of 2250cm shaft leaving 50cm distance between each wheel and 75cm on right and left side beyond each corresponding wheels. These designs were made considering the average height of the standing rice crop which is normally three feet from ground level above which the center axle position coincides so as to move freely without obstruction by the standing crop. Likewise, the position of large tread wheels fixed at narrow distance between each as to reduce the angle of coverage that could save the crop from damage while the machine takes turn reaching tail end of field /near bunds. The machine has a steel made cell type seed metering mechanism with 15 cells on the periphery of each solid wheel totaling 9 Nos. accommodated @ 3Nos. in each seed hopper numbering 3 which are mounted on the center axle. Shoe type furrow openers 9 Nos. provided at a spacing of 25cm between each. A single wheel driven unit powered by a 4.0 HP diesel engine is attached for operation of the machine by an operator provided with seat. As observed on the performance results of the Rice- fallow pulse planter, the cost of operation was 76% higher in manual random dibbling method of sowing over sowing by Rice-fallow pulse planter. Whereas, it was Rs 1250/- higher in Sowing by Rice-fallow pulse planter when compared to conventional practice of Broadcasting method of sowing.The results of the field crop experiment revealed that the crop sown with Rice-fallow pulse planter significantly increased the growth parameters viz., germination (93.66 %) crop stand (32.37 Nos. m^{-2}) besides registering the grain yield to the tune of 839 kg ha^{-1} which was 20.72 and 55.66% higher than rill placement and broadcasting respectively.

Keywords- Line sown rice, Rice-fallow pulse planter, Standing rice crop condition, Wetland rice ecosystem

I. INTRODUCTION

Ever since farmers started cultivation of rice, growing legumes in rice-fallows has also been under practice in wetland ecosystem wherein it is raised either as relay cropping in the standing crop of rice at 7-10 days before its harvest by broadcasting method or manual dibbling randomly immediately after rice harvest so as to efficient utilization of residual moisture and nutrients left out by the preceding rice. Usually pulse sowing is performed either with blackgram or greengram in waxy condition that prevails at the above said stages following more moisture retentivity in clay loam nature of wetland field's soil. Nevertheless, rice is extensively grown in South Asian countries like Bangladesh, India, Nepal, Pakistan and Sri Lanka wherein the satellite image analysis estimated that rice area during 1999 kharif and Rice-fallows during 1999 / 2000 rabi were about 50.4 and 14.29 million ha respectively. It resulted in 36.11 million ha as fallow during rabi which has substantial scope to increase cropping intensity by introducing a short-season legume as second crop. Subbarao et al. (2001) reported that growing legumes in rice-fallows is profitable for the farmers with a benefit-cost ratio exceeding 3.0 due to low input use besides employment generation of 584million person-days for South Asia. The slow growth in pulse production compared to enormous increase in human population led to progressive decline in availability of pulses from 70 gram/adult /day in 1960-61 to less than 40 grams during the present decade. This has caused great concern among policy makers, administrators and researchers (Pushpa M. Savadatti, 2007). Pulses are cultivated under rice fallow conditions in about 2.6 lakh hectares in Tamil Nadu which is 30.75% of the total area under pulses in this state. Rice fallow pulses contribute about 40.5% of the total pulse production (Ramanathan, 2000).However, the widely followed farmers' practice of either broadcasting seeds in the standing crop of rice fields as relay cropping or manual random dibbling immediately after rice harvest leads to often crop failure owing to poor germination of seeds due to uneven distribution with improper depths in broadcasting and at varying in spacing in manual random dibbling. Even there are emerged seedlings, it started drying at random subject to the residual moisture availability, soil type and depths at which the root growth takes place, which ultimately cause either poor crop stand or complete crop failure. Further, under broadcasting and random dibbling, uneven crop stand results in competition between plants for resources like light, moisture, space and nutrients in densely grown areas and poor resource use and grand weed growth in sparsely grown areas. As a result, there will be reduced crop growth and yield in both the cases on one hand and complete crop failure on the other which warrants a suitable intervention. Broadcasting of seeds is normally adopted for sowing of various crops, which not only consumes more man-power but also affects the crop stand, resulting in poor yield (Singh, 2014). Line sowing is the most efficient means of sowing the crops and most ideal for crop management (Devnani, 1989).The main objective of this study is to design and develop a pulse planter suited to perform sowing of rice fallow pulse in the standing crop of line sown rice at maturity stage without damage to the rice. Specific objectives were to optimize plant and row spacing of both rice and rice fallow pulse suited to sowing with Rice–fallow pulse planter and to establish performance index for the planter, identify performance indices with reference to economic viability and compare the performance of the planter and manual sowing. Upon noticing above need triggered devising of Rice-fallow pulse Planter at Agricultural College &Research Institute, Madurai under the project funded by Department of Science and Technology, New Delhi, India during 2012-2016.The planter not only enables the seeds to place at required spacing with proper soil depths, but also desired seed rate which are imperative for maintaining uniform crop stand and better establishment.

II. MATERIALS AND METHODS

2.1. Design considerations

The basic design considerations in the development of the Rice-fallow pulse planter were:

- Designing of planter was done to develop the machine required for sowing the pulse seeds for eg. Blackgram (or) greengram (or) suitable pulses as rice fallow pulse in standing crop of rice at 7 to 10 days before its harvest.
- The planter was designed in such a way that it could operate in the rice cropped field neither any damage to crop nor obstruction to the machine and will ensure sowing of pulse seeds at proper spacing in between the standing rice hills at an appropriate depth (Fig.1).
- The machine was designed with help of widely employed, most popular and recently evolved software Pro-E exclusively used in designing all types of machines.

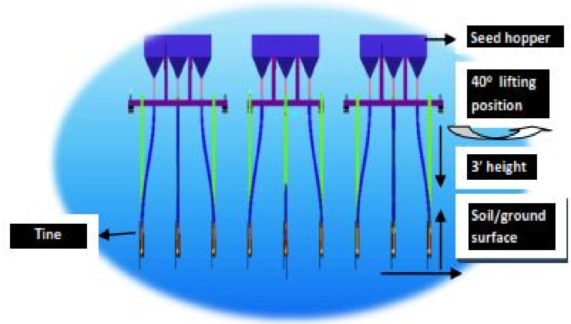

Fig.1.Seed Hoppers, rectangular frames, furrow openers and Hydraulic lifting System (Design with Pro-E)

- On completion of designing all components of the machine, the part file of each and every components were taken for analyze the parameters like strength, stress etc. with help of ANSYS software to optimize the dimension suited for. With the results obtained from the ANSYS, the modification on each and every components has been done then and there until the optimum values are obtained and material chosen for each components followed by fabrication. The fabricated machine has been taken to the open field to test verify the machine by taking observations on several parameters related to machine and according to that modification could be made until satisfactory results are obtained.
- As soon as completion of design of machine with Pro-E software, each component was analyzed with help

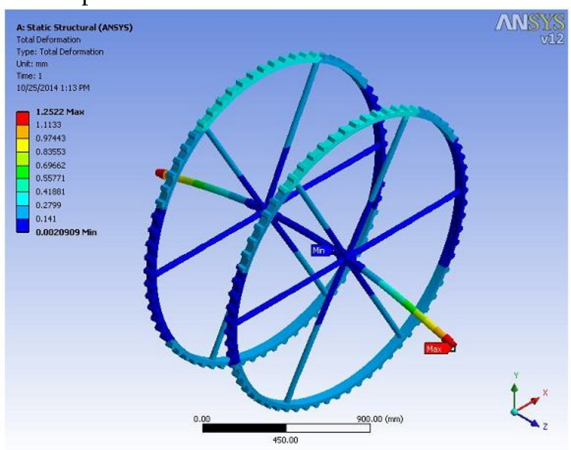

Fig.2. Load v/s stress analysis of Center axel and Rear wheel with ANSYS

of ANSYS static structural analysis to determine the stress of the same. Amongst the components, the vital viz., center axle and rear wheel of the machine were applied with Load v/s stress analysis and their results are as follows (Fig.2).

Load calculation

1. Total weight without rear wheel, axel and bearing: 460 Kg
2. 460 Kg is spited in six axel support.
3. 460/6 = 76 Kg. say that 75Kg
4. 75Kg x 9.81 = 735 N applied downward.
5. The rear wheel is fixed in "Y" axis.

Result

1. The working stress is 270 MPa = 270 N/mm^2 (from ANSYS).
2. Ultimate stress of the steel is 460 MPa.
3. The design result of stress is within the limit.
4. The design is safe.

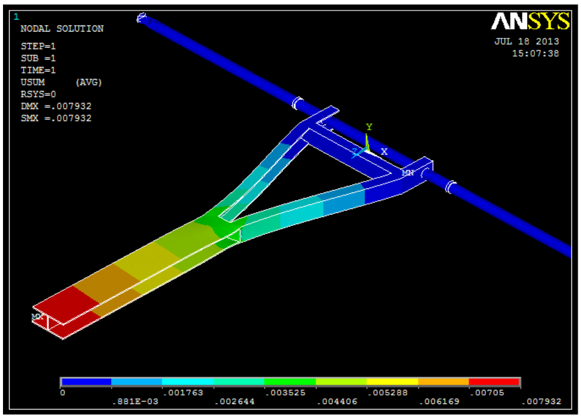

Fig.3.Application of ANSYS on Channel thickness/shape for chassis

Material Mild Steel (150X75mm); Thickness of front I Section=5mm; Shaft dia=40MM; Force on Front of C Section=9000N; Displacement of Two Wheels=150MM; Horizontal Loads on Two Holes=1500N, 1500N; Max Stress=19.807 N/mm2; Max Deflection=0.007932mm

Results: "I" Section is Preferable as it gives less deflection and stress compared among all 'C' section (Fig.3).

2.2. Constructional details

A sowing machine namely "Rice-fallow pulse planter" was designed and developed at Agricultural College and Research Institute, TNAU, Madurai, India with the specifications as given in the Table 1.

The machine (Fig.4) comprises of three seed hoppers with three compartments each, provided with openable cover and are being mounted horizontally over rectangular frame connected by two arm like M.S flats; these are positioned above the rear wheel's central axle; there are three steel made cell type seeding wheel beneath inside upward from lower part of each hopper; the seeding wheels are being connected with spur gears viz., small and bigger sizes mounted on seeding wheel rotating shaft and rear wheel's hub respectively, from which power transmission act to rotate seeding wheel; a chassis to facilitate traction of sowing unit; a pair of rear wheels being connected by a shaft (Central axle) having above said three seed hoppers, first one at middle of two rear wheels, second and third at left and right side beyond the corresponding wheels; a single fore wheel driven unit consists of a gear box connected with an 4.0HP engine at top being attached to chassis facilitates driving of entire unit of machine; a total of nine furrow openers touching ground being connected at the lower end of the square pipes connected to center axle shaft; the sowing unit also consisted of seed hoses and soil closers 9 Nos. each fixed behind each furrow opener numbering 9; and a driver seat provided on midpoint of chassis connecting both sowing unit and driving unit facilitates easy operation of planter; wherein the motion of rear wheels and of front wheel is achieved by driving mechanism gets converted through said gear box and leads to an adjustable, forward and simultaneously motion of said planter to ensure proper sowing of pulse seed in rice cropped field.

The center axle connecting two rear wheels is positioned at 3' height from the ground level which coincides well above the average height of crop so as to operate the machine without any damage to the standing rice crop while sowing. The closer distance of 50cm between two rear wheels position on the center axle facilitates the machine to easy turning due to reduced area of angle of coverage over the land leaving standing rice crop free from obstruction and damage. To give easy pass to furrow openers (9 Nos.) in standing rice crop, their position of 25cm between each is being equal as that of standing crop hill row spacing of 25cm. In addition, the lifting mechanism from the Hydraulic system lifts at 40^{o} angle in front the furrow openers (9Nos.) together with seed hoppers and their supporting rectangular frames which avoids damage to standing rice crop while the machine takes turn at tail end near field bunds and also to the furrow openers while road run.

Table: 1Technical specification of the "Rice- fallow pulse planter"

Overall Dimension LxWxH (mm)		3050x2250x1800
Weight (kg)		375 kg
Power	Model	165F Single cylinder Air cooled Diesel Engine
	Rated power (kw)	2.94 kw(4.0HP)
	Rated speed (RPM)	2600r/min
Travelling mechanism	Type	Single wheel driven (Steel Wheel)
	Planting speed (m/min)	33m/min (297 dibblings / min)

	Road travelling speed km/hr	5.46
Seeding mechanism	Area coverage(ha/hr)	0.36
	Row number	9
	Row spacing (mm)	250
	Distance between seed (mm)	100
	Seeding depth (mm)	30-40
	Capacity ($m^2 hr^{-1}$)	3600

Fig.4. "Rice- fallow pulse Planter" in road run condition

2.3. Field evaluation

Field trials were conducted in the wetland field having sandy clay loam soil of Central farm at Agricultural College and Research Institute, TNAU, Madurai to evaluate "Rice- fallow pulse planter" for sowing rice-fallow pulse in the standing crop of line sown rice field 10days before its harvest. The field trials were imposed with treatments like spacing viz., 25x10, 25x15, 30x10 and 30x15cm in subplots and sowing methods include Rill placement, sowing by manual dibbling and sowing by "Rice-fallow pulse planter" in main plots under split plot design with three replications for optimization of spacing and to compare various sowing methods. Necessary observations were recorded on crop and analyzed statistically. Machine performance parameters like effective field capacity, field efficiency, speed of operation, depth of sowing and labour requirements were determined as per the standard procedure and compared with the conventional practice.

2.4. Cost analysis

A cost analysis was made based on the procedure given in the IS Code (Indian Standard Institution, 1979). The useful life of Rice-fallow planter was assumed to be 8 years and the annual use was assumed to be 90 h.

III. RESULTS AND DISCUSSION

The field performance of the developed "Rice-fallow pulse planter" was conducted in the wetland field of Central farm at Agricultural College and Research Institute, TNAU, Madurai during spring seasons of 2014 and 2015.

3.1. Field performance of Rice-fallow pulse planter

Table 2.Performance results of Rice-fallow pulse planter for sowing pulse in standing rice crop condition

Parameters	Rice-fallow pulse planter	Manual Dibbling	Broadcasting (Conventional)
Location	Institute farm	Institute farm	Institute farm
Name of crop sown	Blackgram	Blackgram	Blackgram
Variety	ADT 3	ADT 3	ADT 3
Season	Spring	Spring	Spring
Speed of operation km h^{-1}	2.77	-	-
Width of the operation, cm	225	-	-
Seed rate kg ha^{-1}	7	15	20
Row to row distance, cm	25	25	-
Germination, %	93.66	67.57	48.24
Plant population m^{-2}	32.37	22.87	18.22
Effective field capacity, ha h^{-1}	0.36	0.016	0.16
Labour required, man-h ha^{-1}	18	64	6.25
Cost of operation, Rs ha^{-1}	1500	6250	250
Yield, kg ha^{-1}	839	539	372

Fig.5. Rice-fallow pulse planter in operation under rice crop stand condition

The performance result of the Rice-fallow pulse planter for sowing of Blackgram is given in Table 2. The Blackgram variety ADT 3 suited for rice fallow pulse was used as test crop in the experiment conducted during spring season of the years 2014 and 2015. The planter was operated in the field by engaging a single person who was trained well. The Blackgram was sown in the standing rice crop condition at 10 days before its harvest and that was compared with manual dibbling and conventional practice of Broadcasting method (Figure 5). The cost of operation was 76% higher in manual dibbling method of sowing over sowing by Rice-fallow pulse planter. Whereas, it was Rs 1250/- higher in Sowing by Rice-fallow pulse planter when compared to conventional practice of Broadcasting method of sowing. However, the grain yield of Blackgram recorded in the plots sown by Rice-fallow pulse planter was manifold (839 kg ha^{-1}) which was 20.72 and 55.66% higher over manual dibbling and conventional practice of Broadcasting method of sowing respectively. This was due to proper placement of seeds at proper depths (3-4cm) in moist zone and at proper spacing of 25x15cm wherein it registered higher germination of 93.66% under sowing by Rice fallow pulse planter. Maruthupandi et. al. (2015) reported that sowing by random dibbling and broadcasting methods of sowing rice-fallow pulse in standing rice crop condition gave significantly lesser yield compared to dibbling seeds in lines manually.

3.2. Total cost of manufactured Rice-fallow pulse planter

The manufactured cost of developed "Rice-fallow pulse planter" was calculated based on the prevailing markets rate of the raw materials used for fabrication of the machine during the year 2012-13 viz. Center axle, large tread wheels, seed hoppers, furrow openers, Chassis ('I'& 'C' section), single wheel driven unit, hydraulic system etc. and man power used for fabrication. The approximate cost of the machine was in Indian Rs.1, 25,000/-.

CONCLUSION

The Rice- fallow pulse planter was developed and tested very appropriate for sowing of rice-fallow pulse in the standing crop of rice condition 7-10days before its harvest in wetland fields without damage to the rice crop. It can be operated in the fields having above said condition anywhere in wetland rice ecosystem as it gave satisfactory results in saving cost of operation and increasing yield to the tune of 21%-55% over traditional methods of sowing.

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