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Residue management through combination of machinery in combine harvested rice field

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Abstract

Rice (*Oryza sativa* L.) is the most important crop of India and it occupies 23.30 per cent of gross cropped area of the country. Straw management and crop rotation alternative to burning straw by using machinery, straw height reduction helps in decomposition of straw. Straw management practice performed in the field of Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G) by using the different combination of machinery i.e. disc harrow, disc plough and rotavator (T_1), stubble shaver, disc plough and rotavator (T_2) to incorporate the straw into soil. The machine parameters were theoretical field capacity, actual field capacity, field efficiency, fuel consumption, energy requirement. The soil properties were moisture content, bulk density, cone Index, pulverization Index, mixing Index and physical properties of straw were moisture content, straw height, weight, straw population considered during field operation. Experiment was conducted by taken two treatments with their five replications comprised of different combinations of independent parameters on experimental field.

Keywords: Straw management, combination of machinery, soil parameters, straw parameters, cost analysis

Introduction

Rice (*Oryza sativa* L.) is the most important crop of India and it occupies 23.3 per cent of gross cropped area of the country. Production and productivity of rice in India at 2017-18 was around 111.01 MT and 2585 kg/ha respectively under the area of 42.95 M ha (Anonymous, 2018). Rice contributes 43 per cent of total food grain production and 46 per cent of total cereal production. In general, farmers operate stubble shaver on paddy straw after harvesting the crop by combine harvester and then burn it. In this process about 12.6 MT of paddy straw is burnt in Punjab every year. It is estimated that paddy straw worth crores of rupees is burnt in the field and 38.0 lakh tons of organic carbon, 59.0 thousand tons of nitrogen, 2.0 thousand tons of phosphorus and 34.0 thousand tons of potash is lost every year in burning of paddy straw (Verma *et al.* 2016) [9]. Management of paddy residues left in the combine harvested fields is a major problem in rice wheat crop rotation in India (Thakur, 2007) [8]. Emission of smoke which if added to gases present in the air like methane, nitrogen oxide and ammonia can cause severe atmospheric pollution (Kumar *et al.*, 2015) [5]. The burning of residue is not only source of atmospheric pollution but also leads to loss of rich organic matter (Thakur, 2007) [8]. Straw management and crop rotation alternative to burning straw by using machinery, straw height reduction helps in decomposition of straw (Cook *et al.*, 2000) [2]. Erosion can be greatly reduced by maintaining a crop residue cover on the soil surface of at least 30 percent after all tillage and planting operations. Conservation tillage is one of the most effective means of cropland erosion control (Kenneth *et al.* 2005) [4]. Stubble length reduced by straw chopper and also found that time for decomposition of straw with straw lengths such as 0.5 cm, 1.0 cm, 2.0 cm and 5 cm were 24 days, 30 days, 47 days and 50 days respectively (Midwood *et al.*, 2012) [6]. The main parameters that affect the performance of the stubble harvester cum chopper were forward speed of the machine, chopper speed, moisture content of the stubbles, height of stubbles, plant density (Thakur, 2007) [8].

Material and Methods

Experimental site

Field experiment was carried out during *kharif* season of 2017-18. Test was conducted in combine harvested rice field of Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyala, Raipur (C.G). The soil of experimental site is represented as a silty clay soil mixed with sand. It is locally called '*Dorsa*'.

Design of experiment

Straw management after cutting straw it was require to mix the straw in soil for proper incorporation, therefore all three operations were taken as combination i.e. cutting of straw, ploughing operation and mixing operation. So different types of implements were required for tillage and mixing operation, that implements were disc harrow (M_1), disc plough(M_2), rotavator (M_3), stubble shaver (M_4). Different combinations of implement are given below.

T_1 = 2 × disc harrow + 1× disc plough + 1 × rotavator
T_2 = 1 × stubble shaver + 2 × disc plough + 1 × rotavator

Fig 1: Mulcher

Fig 2: Stubble shaver

Fig 3: Disc harrow

Fig 4: Rotavator

Machine parameters are theoretical field capacity (ha/h), actual field capacity (ha/h), field efficiency (%), fuel consumption (l/ha) and energy requirement (MJ/ha). Physical properties of soil are, moisture content (db %), bulk density (g/cc), cone Index, pulverization index and mixing Index. Physical properties of straw are moisture content (db %), straw length (cm), weight (g), straw population, straw uprooted efficiency (%). Each replication for every treatment was carried out in a separate plot. The result for each dependent parameter soil (pulverization index, mixing index, reduction in bulk density), machine parameters and straw parameters with replications were analyzed on experimental field.

Soil parameters

Moisture content of soil

The soil moisture analysis was done by oven drying method. Randomly soil samples were collected from selected field and weight of the wet soil sample was measured by weighing balance. The soil sample was put in hot air oven at 105^o C for 24 hours and then the weight of dry sample was measured. Moisture content was measured by using following relation:

$$\text{Moisture content (\%)} = \frac{w_1 - w_2}{w_1}$$

Where,
w_1 = initial weight of soil sample, g
w_2 = dry weight of soil sample, g

Bulk density of soil

Bulk density of soil is the ratio of mass and volume of soil. The bulk density was determined after the operation using core cutter and hammer. The diameter and length of the core cutter was 10 cm and 17.5 cm respectively. Soil samples were collected from each experimental plot and weighted. The samples for drying were placed in an oven at 105^o C for 24 hours. The dried samples re-weighted in an electrical balance meter having maximum capacity to weight 5 kg and the difference was recorded. Bulk density was calculated by using following formula:

$$\text{Bulk density} = \frac{\text{mass of soil sample}}{\text{volume of core cutter}}$$

$$\rho_b = \frac{M}{\pi D^2 L}$$

Where,
D = bulk density, g/ cm^3
M = mass contained in soil sample of oven dry soil, g;
V = volume of cylinder sampler, cm^3
D = diameter of cylinder sampler, cm; and
L = height of cylinder sampler, cm.

Organic carbon

Organic carbon was determined by Walkley and Black‟s rapid titration method (Walkey and Black, 1934). The procedure of determination of organic carbon content is given below:

C in soil (%) = [(B-T) × S × 0.003 × 1.3 × 100] ÷ W

Where,
B = amount of $FeSO_4$ required in blank titration.
T = amount of $FeSO_4$ required in soil titration.
S = strength of $FeSO_4$ (from blank titration).
W = weight of the soil.
Organic matter in soil (%) = % organic C × 1.724

Straw parameters

Moisture content of straw

The straw moisture analysis was done by oven drying method. Randomly straw samples were collected by selected field. The weight of the straw samples was measured by weighing balance. The straw sample was put in hot air oven at 70 °C for 4 days and then the weight of dry sample was measured. Moisture content of straw was measured by using following relation:

$$\text{Moisture content (\%)} = \frac{w_1 - w_2}{w_1}$$

Where,
w_1 = Initial weight of soil sample, g
w_2 = Dry weight of soil sample, g

Straw length

The length of straw was taken before the operation of implements and after the operation of implements in combine harvested rice crop field. The length of twenty straws was taken randomly from each plot and average was taken. The length of straw was measured with the help of measuring tape.

Weight of straw

Straw taken randomly from each plot by using 1 m^2 area frame and weight was measured by using weight balance the average was taken as weight of straw.

Straw population

Initial straw population of combine harvested rice crop was calculated using a square frame of area 1x1 meter placed randomly in the experimental field where the operation was performed. Five observations were taken from each plot and then average value of straw population was calculated in per meter square area.

Fuel consumption

In weeder petrol start, kerosene operated engine was used. The fuel consumption measured in terms of liter per hour by additional measuring cylinder. The following formula was used for measuring the fuel consumption (FC).

$$FC = \frac{\text{amount of Fuel required for operatoin (lit.)}}{\text{time of operation (h)}}$$

Theoretical field capacity

Theoretical field capacity was determined by speed of the machine and effective width of the implement. The formula used is given below

$$TFC = \frac{S \times W}{10}$$

Where,
T.F.C. = theoretical field capacity, ha/h
W = effective width of weeder, m
S = speed of operation, km/h

Effective field capacity

The actual covered area during operation was called effective field capacity. In this term we consider the useful time and time loss for turning the machine.

$$EFC = \frac{A}{T_p + T_l}$$

Where,
E.F.C. = effective field capacity, ha/h
A = area, ha
T_p = productive time, h
T_l = nonproductive time, h

Field Efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity. The following formula was used for determine field efficiency.

$$FE = \frac{EFC}{TFC} \times 100$$

Where,
FE = Field efficiency, %
E.F.C. = effective field capacity, ha/h
T.F.C. = theoretical field capacity, ha/h

Energy analysis

Energy was required to operate the machinery in field there was mainly three type of energy used i.e. human energy, chemical energy (Fuel energy) and machinery energy. The energy of the operation is calculated by following the research article (Singh *et al.*, 1992) [7].

Cost analysis

Cost of operation performed for all treatments was worked out on the basis of the prevailing input. The cost of operation of is divided into two heads known as fixed cost and operation cost, where fixed cost is independent of operational use while variable cost varies proportionally with the amount of use (Kamboj *et al.*, 2012) [3].

Result and Discussion

Soil parameters

Bulk density of field observed before and after operating the combination of different implement as treatment T_1 and T_2 i.e. shown in Table 1. The maximum reduction in bulk density was observed in T_2 that was 21.64 % and for T_1 18.93 %. Carbon content improvement was observed maximum in T_1 that was 18.12% and 8.90% for T_2.

Table 1: Moisture content, bulk density and carbon content of soil during experiment

Sample	Moisture content, %	Bulk density, g/cc		Carbon content, %	
		Before operation	After Operation	Before operation	After Operation
T_1	16.84	1.69	1.37	0.55	0.65
T_2	15.71	1.71	1.34	0.56	0.61

Table 2: Fuel consumption, speed, field capacity and field efficiency of different implements

Machinery	Fuel consumption, l/h	Average speed, km/h	TFC, ha/h	EFC, ha/h	Field efficiency, %
Disc harrow	7.20	3.50	0.74	0.61	82.70
Disc plough	7.80	3.06	0.45	0.39	86.22
Rotavator	8.38	3.10	0.46	0.40	87.39
Stubble shaver	5.03	2.84	0.42	0.37	87.62

Machine parameters
Operational speed, fuel consumption field capacity and field efficiency of different implement is given in Table 2.

Straw parameter
Average straw population was found 302.9 per m^2 and weight of straw was found 604.08 g per meter square. Moisture content was observed before perform different combination of implement for straw management given in Table 3. Straw length reduction was found more in T_1 than T_2 given in Table 3. The maximum reduction in straw length in T_1 was observed 69.81 % and 65.28 % for T_2.

Energy and economical analysis
Energy requirement by different implements of different treatment are shown in Fig. 5. Minimum energy requirement observed in treatment T_1 that was 13.62% less than the T_2. The calculated energy requirement of different treatment is show in Table 4. Cost of operation of different treatments is shown in Fig. 6. Minimum cost of operation calculated in treatment T_1 that was 16.67% less than the T_2. The calculated cost of operation of different treatment is represented in Table 5.

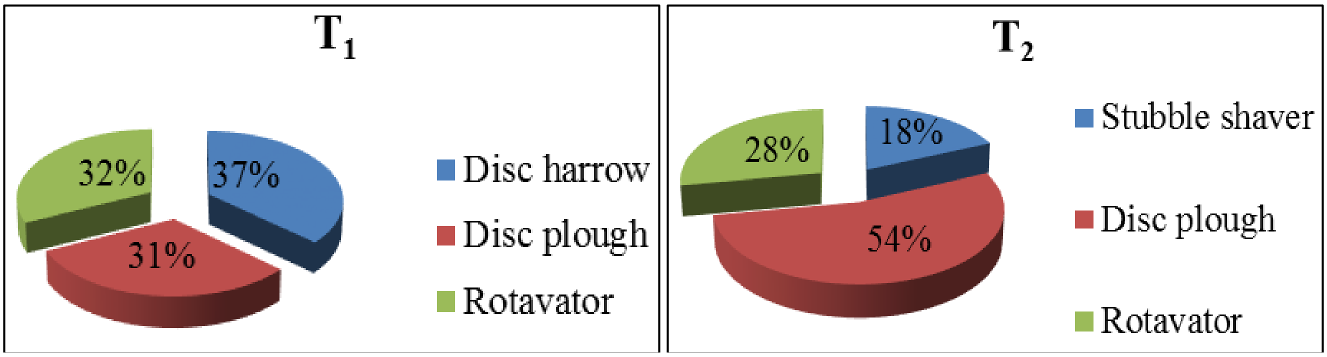

Fig 5: Energy requirement in per cent of different implements under different treatments

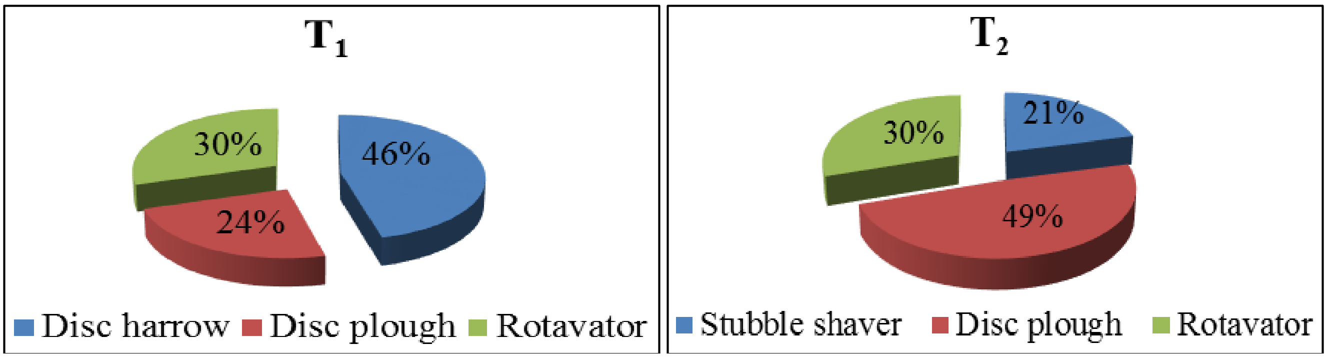

Fig 6: Cost of operation in per cent of different implements under different treatments

Table 3: Average moisture content and straw length during experiment

Treatment	Moisture content, %	Straw length, cm	
		Before operation	After operation
T_1	15.96	42.93	12.96
T_2	15.73	44.10	15.31

Table 4: Energy requirement of the different treatments

Treatments	Combination	Energy, MJ/ha
T_1	$2\times M_1 + 1\times M_2 + 1\times M_3$	3738.12
T_2	$1\times M_4 + 2\times M_2 + 1\times M_3$	4327.55

Table 5: Cost of operation of different treatment

Treatments	Combination	Cost, ₹/ha
T_1	$2\times M_1 + 1\times M_2 + 1\times M_3$	6160.10
T_2	$1\times M_4 + 2\times M_2 + 1\times M_3$	7392.94

Conclusion
The observed data reveled that straw length reduction was helping more for straw incorporation in soil because in T_1 two pass of harrow reduce the size of straw more than the machinery used in T_2 that was help to reduce the bulk density and also increase the carbon content by better incorporation of soil. Energy and cost of the T_1 was found 13.62% and 16.6% less than the T_2 respectively.

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