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# Recycling Plant Residues as Organic Fertilizers

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## ABSTRACT

Overcoming environmental pollution arising from plant residues *e.g.*, rice straw, wheat straw, and maize stover will be realized by recycling it as organic manure direct in the soil. Attainment of this aim, the plant residues must be cut up into small parts in order not to retardation tillage systems from mixing and concealment it in the soil. Therefore, a cutting unit machine was developed and tested under Egyptian circumstances. More than 90 % of cutting rice straw had a 4.0 cm length and was distributed in the most harvesting areas. The rotary tiller spread the cutting rice straw in the tilled soil into 56 and 44% at 0.0-5.0 and 5-10 cm, respectively. The microbial activity was improved and reached the highest population density after 8 weeks from tillage and sowing. For three months, the cutting rice straw was completely decomposed and amalgamated into the soil. The cutting straw treatment recorded decreasing in soil penetration resistance.

***Keywords:*** Rice straw, wheat straw and maize stover

## INTRODUCTION

Egypt is known for what is called 'the Black Cloud," a thick layer of smog from burning rice straw that spreads across Cairo for an extended period (El-Dewany *et al.*, 2018). Rice straw is rich in nitrogen, potassium, potassium, carbon and silicon. It is, however, seldom put to agronomic use by farmers in Egypt, mainly owing to a lack of awareness of the plant nutrients quantity present and a lack of simple and inexpensive recycling methods (Gewaily, 2019).

Crop residues are important natural resources and upon decomposition during incorporation may cause enhanced soil properties and improves the overall ecological balance of the crop production system besides building up soil organic matter and soil nutrients *e.g.*, N, P and K (Duan*et al.*, 2021). Sufficient organic matter is necessary for keeping soil fertility and the performance of crops, although organic manures alone cannot ensure sustainable plant production (Duan*et al.*, 2021).

In soils which are either well-drained or imperfectly drained, rice straw can be recycled by direct incorporation after the first ploughing (Pathak*et al.*, 2006). Rice straw can also be spread on the surface of the land and rice seedlings transplanted. Another method is to add straws among rows of transplanted rice. Further, rice straw can be converted into compost without the addition of any low C/N substances by merely heaping on a part of the paddy field (Xian *et al.*, 2020).

The objective of the current investigation is to develop a combined cutting unit with a rice-harvesting machine for investigating the possible effects of recycling rice straw under field circumstances using a rotary tiller system on some soil properties.

## MATERIALS AND METHODS

**1. Location.**

The current investigation was performed during the season of 2020 in a private farm located in Sedi Salem District, Kafr Elsheikh governorate, Egypt.

**2. Cutting unite and penetrograph.**

The design was modified in this work, where inclined sides were added to compulsion the straw passed through the cutting knives (Fig1). A spiral distributor was added to scatter the cutting straw auf the total harvested area. A reduced tillage system by rotary tiller (160 cm working width, 36 L share form in six groups) was used for preparing the seedbed after rice harvesting, which was covered with the cutting rice straw. The experimental area was planted using the band width sowing method. The cutting straw sample was accumulated in a sack during harvesting. The samples were taken randomly from three different places in each treatment. Three working division were taken (<4, 4 and >4 cm).The length of the cutting straw was measured by the meter. The weight of each division was found and percent of each of them was calculated to the total weight of the sample. The distribution of cutting straw was determined by using a wooden frame (130X45 cm). The frame was divided longitudinally into five parts. The frame was sited randomly of the cutting straw after harvesting in the perpendicular direction of harvesting. Straw was collected in each part and weighted. The distribution of cutting straw was expressed as a percentage of the total straw weight of the sample. The average of three repetitions was taken for each treatment as the percentage of the straw distribution.The soil penetration resistance was measured with a penetrograph. The penetrograph consists of 15 parts according to Eijkelkamp catalogue (1979). The penetrograph is driven into the soil at a uniform speed; the resistance is measured and registered in N/cm$^2$ **.**

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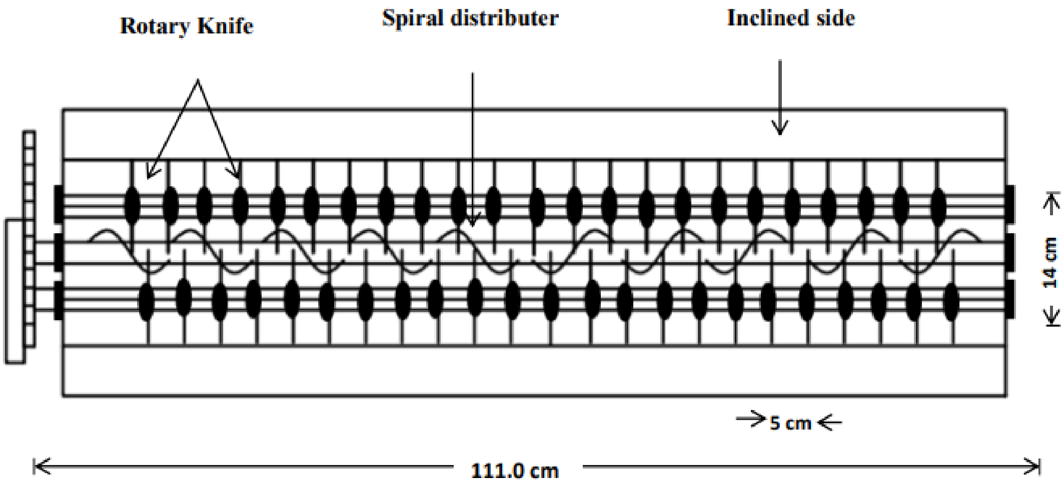



**Fig1. Cutting unite**

**3.Soil sampling and analysis.**

Crop residual (straw rice ) was separated from the soil samples by using the wet sieving technique. The soil samples were taken from three different locations at two levels of depth (0-5 and 5-10 cm) after days from adding in soil. Crop residuals extracted four times from soil samples after tillage, 4, and 8 weeks from tillage and sowing. The extracted crop residual in each sample was weighted to achieve a percentage ratio in each depth. Soil samples from (0-10 cm) depths were collected five times after application of treatments and analyzed for their different characteristics according to Sparks*et al.*, (2020).

**Table1. Initial soil properties.**

| Initial soil characteristics | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Particle size distribution (%) | | | | Texture class | Field capacity | Wilting point | Saturation | Available soil nutrients | | | EC, $dSm^{-1}$ | pH |
| C. Sand | F. Sand | Silt | Clay | | (%) | | | N | P | K | | |
| | | | | | | | | (mg $kg^{-1}$) | | | | |
| 1.60 | 23.20 | 23.6 | 51.60 | Clay | 42.0 | 21.00 | 84.0 | 48.95 | 7.10 | 200.1 | 2.33 | 7.90 |

## RESULTS AND DISCUSSION

### Cutting straw length and distribution

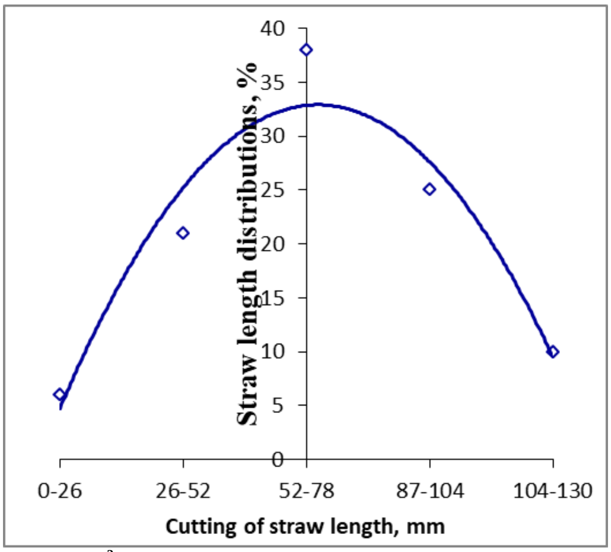
Data of Table 2 showed the effect of cutting unit's operation conditions on the length of the cutting straw. It is shown that cutting straw length is affected by rotary knife speed, straw moisture content, knife clearance and distance between the following knives. The straw moisture content was 44%. The cutting knife speed was13.6 m/s. Knife clearance was 1.0 mm and the distance between the following knives was 4.20 cm. This operation conditions recorded the cutting unit about 90% straw parts with 4.0 cm, 3.0 % straw parts longer than 5.0 cm and 7.0 % shorter than 4.0 cm.

**Table 2. Distribution of cutting straw length**

| Cutting straw length, cm | Cutting straw,% |
|---|---|
| Longer than 4.0 cm | 3.00 |
| 4.0 cm | 90.0 |
| Shorter than 4.0 cm | 7.00 |

From the above data, it may be noticed that the cutting unit with the above operation circumstances is the most suitable unit to prepare and use the rice straw as organic manure direct in the soil.

The results shown in Fig 2 illustrate that more than 84% of total cutting straw was distributed 60% from the harvesting area. To improve the cutting straw distribution on the total harvest soil surface, the cutting unit will be supplied with spiral distributors, which operate in two directions.




$y = -6.4286x^2 + 39.771x - 28.6$
$R^2 = 0.9179$

**Fig. 2. Cutting straw distribution on the harvesting.**

**- Soil penetration resistance**:

The variations of soil penetration resistance consequential on using rice straw are shown in Table 3 and Fig 3. The results showed that using the rotary tiller reduces the soil penetration resistance in tillage zone between 8 and 15.5% compared to soil penetration resistance before tillage (B).

After 4 weeks, the treatment R(S) "rotary tiller in soil covered with cutting rice straw" recorded an apparent decrease of soil penetration resistance at soil layer 2.5 cm depth. Whereas the reduction was less at the treatment of (R)"rotary tiller in soil without cutting rice straw" compared to (R(s)). After 8 weeks, the soil penetration resistance increased at treatments of R(s) and R. At soil layers, 2.5-8.0 cm depth, the reduction of soil penetration resistance was nearly 15.0 and 11.0% and the increase after 8 weeks was 1.8 and 2.8% at treatments R(S) and R respectively. From the above results, it may be noted that the addition of rice straw and mixing it with soil improve the soil's mechanical properties and keeps it for a long time.

**Table 3. Effect of rice straw on soil penetration resistance.**

| Soil depth, cm | Soil penetration resistance, N/cm$^2$ | | | | |
|---|---|---|---|---|---|
| | B | R(S) 2 week | R(S) 6 week | R 2 week | R 6 week |
| 2.50 | 195 | 172 | 174 | 180 | 185 |
| 8.00 | 205 | 174 | 175 | 183 | 187 |
| 13.0 | 208 | 196 | 197 | 197 | 198 |
| 18.0 | 190 | 189 | 190 | 191 | 191 |

**R(S):"rotary tiller in soil covered with cutting rice straw"**
**R:"rotary tiller in soil without cutting rice straw"**

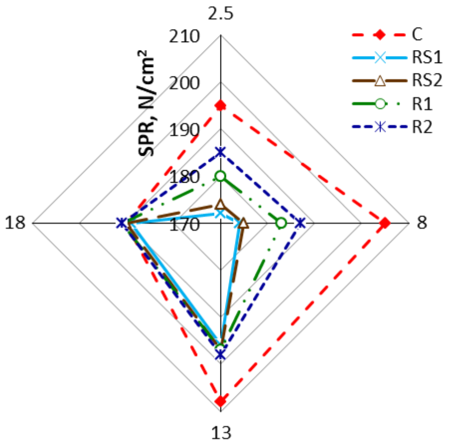



**Fig. 3. Effect of rice straw on soil penetration resistance.**

**- Crop residual:**

Data in Table 4 and Fig 4 showed the impact of the rotary tiller on the distribution of the separated rice straw in the various layers of the studied soil and also, the influence of soil mites on rice straw decomposition during the vegetation period.

**Table 4. Rice straw residual percentage through the following season (The added cutting rice straw was 3.20 Mg fed$^{-1}$).**

| Samples times | Crop residual , % | |
|---|---|---|
| After tillage and sowing | 0.0 -5.0 cm | 56 |
| | 5.0 -10.0 cm | 44 |
| 4 weeks after sowing | 0.0 -5.0 cm | 20 |
| | 5.0 -10.0 cm | 18 |
| 8 weeks after sowing | 0.0 -5.0 cm | 6 |
| | 5.0 -10.0 cm | 2 |
| 12 weeks after sowing | 0.0 -5.0 cm | -- |
| | 5.0 -10.0 cm | --- |

The rotary tiller distributed the separated rice straw in the tilled soil into 56.0 and 44.0% at 0.0-5.0 and 5.0-10.0 cm respectively. After 4 weeks from tillage and sowing, the percentage of separated rice straw decomposition was about 64.0 and 61.0% at soil layers 0.0-5.0 and 5.0-10.0 cm respectively, while the percentage of separated rice straw decomposition increased to 91 and 95% after 8 weeks respectively. After 12 weeks, the results showed that the total separated rice straw was decomposed and amalgamated in the soil. Thus, the results clearly illustrated that the rice straw was completely decomposed and amalgamated in the soil during 3 months after both tillage and sowing.

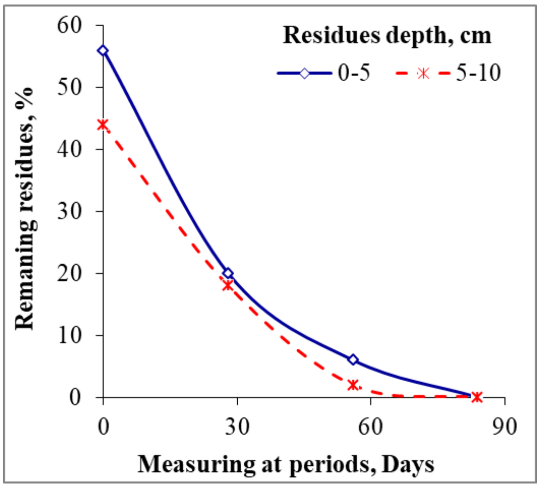


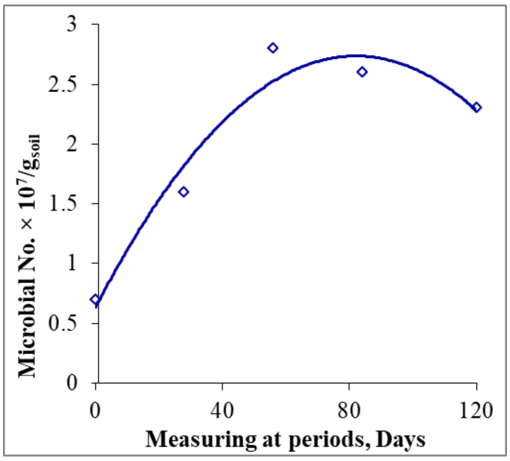

**Fig. 4. Rice straw residual percentage through the following season (The added cutting rice straw was 3.20 Mg fed$^{-1}$).**

**- Microbial numbers:**

On the other hand, the microbial population density was very few at the beginning of the following vegetation season. Data in Table 5 showed increasing twofold in the microbial population density after 4 weeks in comparison with the population density before tillage and sowing.

**Table 5. Microbial numbers.**

| No. of soil samples | Microbial numbersX10$^7$/g soil |
|---|---|
| Before tillage and sowing | 0.7 |
| 4 weeks after tillage and sowing | 1.6 |
| 8 weeks after tillage and sowing | 2.8 |
| 12 weeks after tillage and sowing | 2.6 |
| Before harvest | 2.3 |




**$MN = -0.2714P^2 + 2.0486P - 1.16$**
**$R^2 = 0.9508$**
**MN= Microbial numbers, Nox10$^7$/g s**
**P= measuring at periods, days after tillage and sowing**

**Fig. 5. Microbial numbers.**

The microbial population density pronouncedly increased and reached the highest values of population density (fourfold) after 8 weeks. Afterwards, the microbial population density decreased gradually until the harvest process and this may be due to the completely decomposition of cutting rice straw, therefore nonexistence the organic matter for feeding.

- **Soil fertility.**

Data in Table 6 illustrate that, the values of N, P and K were affected by microbial activity and cutting rice straw addition, where it can be noticed increasing the amount of N, P and K during the vegetation period until the rice straw completely decomposes. Afterwards, the amount of these nutrients decreased gradually until harvesting and this may be attribute to the plants and soil mites being nourished by the soil metals until the end of the vegetation period.

**Table 6. Soil properties.**

| Properties | Time of samples | | | | |
|---|---|---|---|---|---|
| | Before tillage and sowing | 4 weeks after tillage and sowing | 8 weeks after tillage and sowing | 12 weeks after tillage and sowing | Before harvest |
| N, mg $kg^{-1}$ | 48.95 | 50.25 | 54.3 | 53.2 | 49.23 |
| P, mg $kg^{-1}$ | 7.10 | 7.48 | 7.89 | 7.75 | 7.35 |
| K, mg $kg^{-1}$ | 200.1 | 210.5 | 219.3 | 217.3 | 206.8 |

## CONCLUSION

The findings confirmed that more than 90 % of cutting rice straw had a 4.0 cm length and was distributed in the most harvesting areas. The rotary tiller spread the cutting rice straw in the tilled soil into 56 and 44% at 0.0-5.0 and 5-10 cm, respectively. Also, the microbial activity was improved and reached the highest population density after 8 weeks from tillage and sowing.

From the obtained results, it can be concluded rice straw recycle considered one of the most important methods for the disposal of rice straw without burning.

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# إعادة تدوير مخلفات النباتات كأسمدة عضوية


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## الملخص


التغلب على التلوث البيئي الناتج عن المخلفات النباتية مثل قش الأرز وقش القمح وحطب الذرة سيتم تحقيقه من خلال إعادة تدويره كسماد عضوي مباشر في التربة. ولتحقيق هذا الهدف يجب تقطيع مخلفات النبات إلى أجزاء صغيرة حتى لا تتأخر أنظمة الحراثة عن مزجها وخلطها في التربة. لذلك، تم تطوير واختبار آلة وحدة القطع تحت الظروف المصرية. ولقد أوضحت النتائج ان أكثر من 90٪ من قش الأرز المقطوع يبلغ طوله 4.0 سم ويتم توزيعه في معظم مناطق الحصاد. تعمل آلة الحراثة الدوارة على نشر قش الأرز المقطوع في التربة المحروثة إلى 56 و44٪ عند 0-5 و5-10 سم على التوالي. تم تحسين النشاط الميكروبي ووصل إلى أعلى كثافة ميكروبية بعد 8 أسابيع من الحرث والبذر.لمدة ثلاثة أشهر، تحلل قش الأرز المقطوع تمامًا وتم دمجه في التربة. سجلت معاملة القش المقطوع انخفاضًا في مقاومة اختراق التربة .