INCREASING THE EFFECTIVENESS OF THE LAND MANURE AFTER IRRIGATED RICE HARVEST

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Abstrac: This paper presents the research progress in minimum tillage at rice harvested area. It investigates a method of soil preparation with a knife roller in the lowland areas, which is a heavy cylinder with parallel blades used to incorporate the straw into the soil and to perform tillage operations. The technique provides anticipation of the land preparation in order to install pasture during the winter and there is an improvement in weed control and reduction of time and fuel consumption in the tillage operations. It is required a lower power when compared with conventional methods like plow and harrow.

Keywords: soil manure; minimum tillage; ratoon cropping; knife roller

Resumo: Este artigo apresenta o progresso na pesquisa de cultivo mínimo em área de arroz irrigado. É investigado um método de preparo do solo com rolo-faca em áreas de várzea, que é um cilindro com lâminas paralelas usadas para incorporar a palha no solo. A técnica proporciona a antecipação do preparo da terra para a instalação de pastagem durante o inverno e com melhoria no controle de pragas e redução do tempo de preparo e consumo de combustível nas operações. Requerer-se uma menor potência de tração do que métodos convencionais empregando arados e grade.

Palavras chaves: manejo do solo; cultivo mínimo; soca; rolo-faca

1. INTRODUCTION

1.1. Agricultural production challenge

In tillage practices, a critical factor to fulfill the current demand of green fertilization (incorporation of green matter into the soil) under a wide range of crop manure is the way to processing of the post-harvest material. Generally, land cultivation of field containing straw or green material, such as crop residues, rice ratoon and spontaneous vegetation, that require a specific operation to treat this material (Canali et al., 2013). In cases based on organic crop production without tillage, often employ rollers with knives for pest and cover crops control with lower yields than conventional production, and there are some problems like lower crop emergence, large amounts of organic residue on the surface and regrown of the cover crops. Luna et al. (2012) suggest that the use of minimum tillage can reduce some of these agronomic difficulties. Usually, the methodologies based on straw incorporation into the soil are considered more expensive to implement, but they are likely more sustainable farming practice when the use of crop residue is optimized to increase the soil organic matter (Whitbread et al., 2003) and as a source of some minerals. According to Rahman et al. (2005) studies with no-tillage in Bangladesh, the rice straw should be incorporated in the soil for the organic matter recycling and to have a long-term effect on soil proprieties. The soil content increased with organic carbon improves the aggregation status, the infiltration rate and there is a decrease in the bulk density (Bhattacharyya et al., 2008). Furthermore, it has been demonstrated that for green manure in combination with crop residue incorporation from the rice-based cropping system, such as the example of Singh et al. (2007), can be beneficial until 15cm deep in the soil physical fertility.

Actually, rice production systems with emphasis on the use of intense crop rotation could tend to present a difficulty because the emergence of weeds, which may reduce the crop yield (Rodenburg et al., 2009; Sanusan et al., 2010) and, in this case, the quality, with mixed presence of phenotypically similar rice such as the red and black rice (weedy rice). Clearly, some weeds are suppressed by conventional tillage, but increase with zero tillage, which practice requests some kind of mechanical weeder, herbicides and associated with water management strategies (Bhagat et al., 1996; Rao et al., 2007). In a study of the use of chemical control for different levels of tillage for weed control, by Andres et al. (2012), verified that herbicide application results in better productivity when it focuses on reducing the seed bank. In this case, more control is achieved using the herbicide together with conventional tillage. However, the presence of residual herbicide in these areas can influence negatively the development of other cultures, after the management of rice (Sudianto et al., 2013). This is an important restriction for the application of the no-tillage methodologies in lowland rice-based crops.

1.2. Development in tillage machinery

In the southern Brazil, responsible to provide over 60% of Brazilian rice production, around one million ha (hectare) of lowlands are used to rice cultivation, where the flood irrigation creates an anaerobic soil environment that needs careful management practices for efficient use of the crops and the fertilizer nutrients (Fageria et al., 2003). The traditional approach to prepare the dry soil for rice sowing in general has been done using plow and harrow to break up and smoothing out the soil surface, with leveler and bund construction as a common practice just before the sowing time, between the spring and summer. In order to deal with all these operations, many types of machinery and a certain number of workers must be necessary. However, during the tillage practices is common to find delays and constrains in time, due to limited quantity of machines and equipment or as a consequence of bad weather conditions. Consequently, a sowing delay can cause a negative effect upon the crop yield. As an answer of this condition, southern Brazilian farmers are adopting an early soil preparation initiated during the autumn almost six months before the crop sowing time. An additional benefit from this methodology is that the land can be ready to be used as a winter crop after the rice harvest, which thus can create an opportunity of crop diversification and to do different management practices.

On the other hand, using conventional methods of soil preparation and adjustment, despite this larger space of time, there are difficulties to work in water saturated soil during the winter rainfall season. Thus, a prototype of a heavy roller with clamped steel knives was tested and improved at the rice harvested fields in Rio Grande do Sul state, which is so-called "knife roller". The feasibility of the equipment in working under soil with high-saturated condition of the land preparation has been very satisfactorily demonstrated. The equipment replaces a number of usual machinery for tillage and causes a lesser impact on soil than the traditional plowing and harrowing. In this way, it adjusts itself to the concept of reduced or minimum tillage (Edminster et al., 1959). The seedbed preparation with this specific tillage equipment and alternative practices focus on the reduction of soil compaction caused by the extra implement traffic, improvement of infiltration through the loose surface layers, increase the level of hydraulic conductivity, reduction in the soil erosion and runoff hazards (Timsina and Connor, 2001). The knife roller described here shows a similarity in mechanical structure and manure strategies to "rotolama", a roller developed in Italy inside the method of crop rice according to nature, "riso secondo natura" (Valsesia et al., 2009). In both cases, tillage operations are applied to the crop residue management and land leveling in the flooded rice field, after the harvest.

Finally, resonance effects depend highly on the proper tillage of the soil (timing, practices, equipment, etc.), which is closely related to farming management strategies. The design of the tillage system to enhance biological control, recycling of organic matter and production yield is discussed more detailed in this paper.

2. Materials and Methods

2.1 Test site

For the study aimed to investigate the quality of knife roller passage on land preparation observation tests were performed in several farmlands in a typical rice production area, located in a radius of 150km around the city of Pelotas, Rio Grande do Sul (52º 20' W and 31º 46' S at 17m above mean sea level), from 2008 to 2010. Where the results of the main test sites are discussed in this work: Capão do Leão (Lowland Experimental Station of Embrapa Temperate Agriculture) and farmlands in Camaquã and Rio Grande. After the rice harvest, the knife roller was used to land preparation of fields with a varying size from 1ha to 40ha of rice ratoon.

2.2 Cultural conditions

These experimental areas received standard management of irrigated rice crop with BRS Querência cultivar (early maturity, 106~115 days, long slender grain type), where an N-P-K fertilizer (5.20.20) was applied at 300kg ha^{-1} at planting and complemented with urea at 150kg N ha^{-1} in two applications. The distance between rice lines was 17.5cm and a seed density of 100kg ha^{-1}. The average rice yield in the region varied between 6.8 and 9.7ton ha^{-1}. At the time of the roller tests, all the fields had saturated soil from irrigation water (Figure 1).

Figure 1. The set of knife rollers in Lowland Experimental Station of Embrapa Temperate Agriculture (Capão do Leão, Rio Grande do Sul).

2.3 Equipment configuration

Two different roller configurations were used according to the field size in order to allow the maneuvering procedures:

- Configuration “a”: 12 blades of 0.10m height (Figure 2), composed with one roller of 3.00m wide and a total weight 1,202kg (empty: 1,032kg, water: 170kg);
- Configuration “b”: 3 sections roller with 7.00m wide (one roller of 3.00m + two rollers of 2.00m) and total weight 2,810kg (empty: 2,410kg, water: 400kg).

The ground speed for the tillage operation was 7km h^{-1} pulled by a tractor powered between 125 and 260hp depending on farmers’ available machinery.

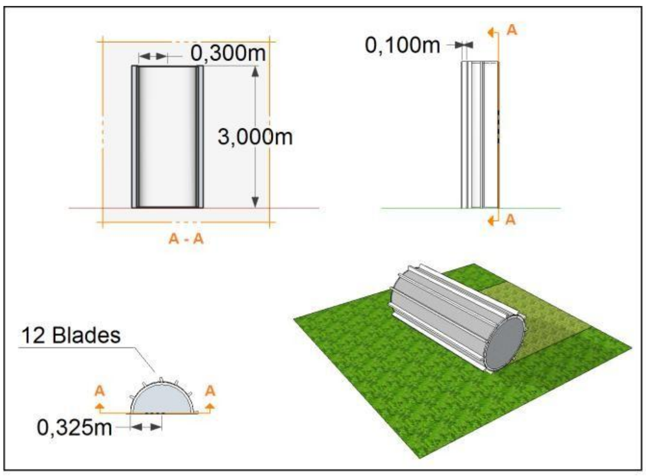

Figure 2. Sketches illustrating the dimensions of paddy field knife roller.

3. Results and discussion

The roller is pulled on the tractor draw bar, which dynamic performance depends on its size and weight, water ballast, blades height, soil type and saturation level, quantity of rice straw on surface, tractor characteristics as wheel/ tire type, engine power and torque, etc. The main part of the farmers is employing available tractor power used before in the traditional tillage, where it is pointed out that a power of 150hp, with dual rear wheels, could pull a set of knife rollers of 7.00m total wide and full weight (configuration “b”). In many of the observational sites, the use of rollers got cheaper results in comparison to traditional methods (between summer and autumn) like tillage by plow, harrow and leveler sequence. In these comparisons, the average fuel consumption with tractor power of 174hp of conventional tillage work from plowing to land leveling is some 80 liters diesel per hectare, while only 31 liters are needed for two roller passages of 7m wide (consumption of 19l h-1), harrowing and land leveling. Besides energy saving, knife roller reduced labor demand and the number of required equipment replacing some of the machinery. Thus, the time required for soil preparation is reduced, as indicated by the field capacity and estimated time of operation in Table 1. The total time, without considering the change of implements, reduces to less than 15% in the case of early tillage for soybean crop seed.

Table 1

Comparative operation time between conventional and knife roller tillage, for soybean/ rice crop implantation after rice crop with a winter lag time

Method	Equipment	Number of times	Field Capacity [ha h-1]	Total Time [h ha-1]
Traditional Tillage (between summer and autumn)	Plow Harrow Lever	1 1 or 2 1 or 2	1.30 1.30 1.00	4.30
Knife Roller Tillage (for soybean crop)	Knife roller	2	4.00	0.50
Knife Roller Tillage (for rice crop)	Knife roller Hallow Lever	1 1 1	4.00 1.30 1.00	2.02

The results with the knife roller showed that land preparation combined with early soil tillage gave a reliable indication of the control in weed infestation after rice harvest and before next crop sowing. In particular, after roller passage, there was the emergence of spontaneous species and many plants of rice, which are wiped out just before the sowing by a burndown herbicide, in a no-till system, or by a passage of a disc harrower, in a conventional system. Using knife roller soon after the rice harvest is over, it occurred more germination and emergence of red rice seeds than in areas no tilled where the intact ratoon remains after the combine passes over the field. From the point of weed infestation management, farmers might choose this option of early land preparation to stimulate the weed germination and thereafter eliminate the emerged plants with another roller passage or using the disc harrower + lever, before the new crop sowing, or herbicide application as an effective weed manure (application of glyphosate at the concentration of 700 – 1,440 g.e.a. ha-1). The experimental testing presented here, is part of a research project of a rice and soybean crop rotation from Embrapa Temperate Agriculture (Capão do Leão, Rio Grande do Sul, Brazil). It was identified a decrease of weed infestation in the 2008/ 2009 season in plots where was used a knife roller methodology (two passes of roller in configuration "a") compared with the traditional tillage technique (1 x moldboard plow + 2 x disc harrow). Two fields of 0.5ha were prepared in April, 2008 with both types of tillage and in the next summer season, the weed grass infestation (mainly Echinochloacrusgalli) was evaluated 30 days after sowing of rice and soybean, as given by Table 2. The soil management with roller decreases 35% of weeds' number in continuous rice culture and 82% in rice-soybean crop rotation system.

Table 2

Comparison of the weed grass infestation in rice and soybean fields prepared with knife roller and conventional tillage (plowing and harrowing). Experimental Station of Embrapa Temperate Agriculture (Capão do Leão, Brazil)

System	Rice	Soybean
	Culms by square meter (±σ)	
Conventional tillage	56 (±7)	75(±10)
Knife roller	36 (±4)	13 (±4)
Percentage reduction (%)	35	82

The conventional seedbed preparation generally is restricted and feasible in dry soil condition. This situation, however, is not always available for most of the lowland fields in South Brazil because the soil type (dense and impervious B horizon) and the weather characteristic of a rainy season in autumn, soon after rice harvest. What implying that in some wet years or in very flat fields, the machinery does not have access to finalize the land preparation, before the beginning of the rice sowing period (between October and November). The delay of the sowing, made after November, affects the grain yield due to unfavorable weather circumstances during crop growth and flowering period. One of the advantages of the knife roller approach, and potentially favorable to this situation, is the possibility of working during a rainfall day; what means that the roller can be applied any time after the rice harvest and gives the opportunity to keep the sowing schedule and outlooks to improve some farm practices. Such models, in Figure 3, can be summarized as a continuous rice crop with a winter lag time; introduction of crop rotation or grazing. The red annulus shows the most common moment for soil tillage with roller by: (a) early soil tillage and following spontaneous vegetation desiccation, (b) land preparation just before new crop sowing during wet season, (c) soil tillage for pasture implantation after rice harvested. The average air temperature, with the maximum and minimum temperatures (vertical line), and total monthly rainfall in 2009 are also presented in Figure 3 as a reference of the climate conditions for tillage procedures. The data comes from Embrapa automatic weather station in Pelotas (RS).

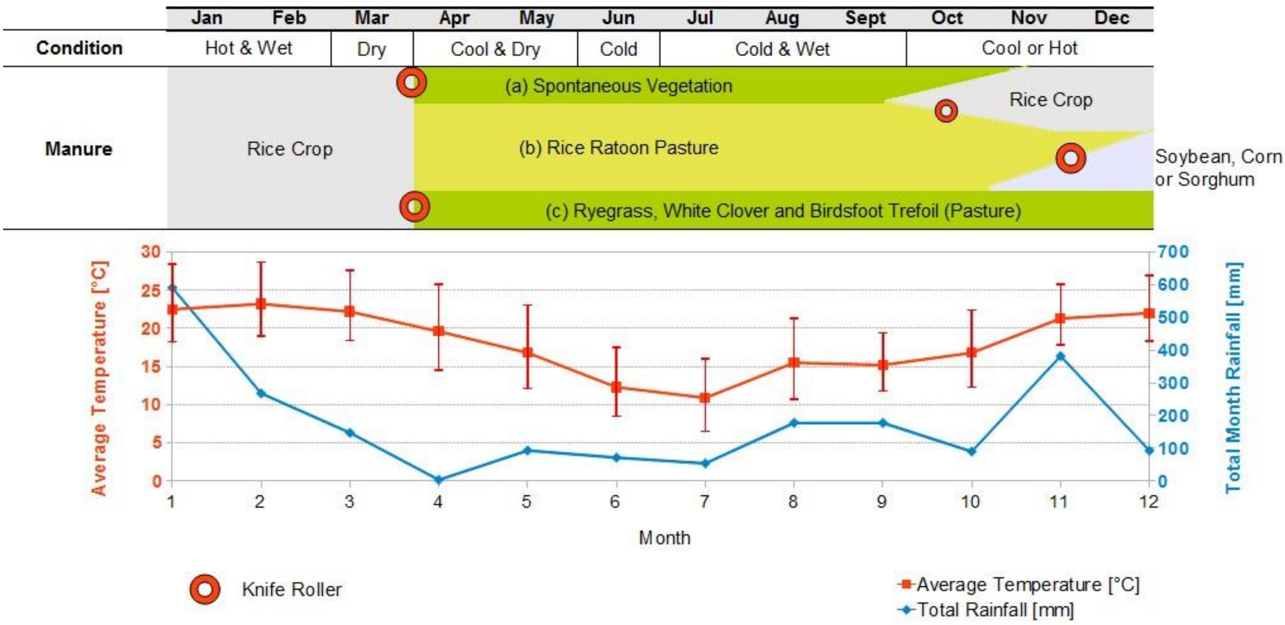

Figure 3. Sequences practiced with paddy field knife roller in South of Brazil and reference average temperature and monthly rainfall (2009).

When the soil adjustment is done in well-saturated condition, the water in the field provides protection against eolic erosion, common issue in dry-land cultivation systems. Nevertheless, it has been observed on knife roller application a potential of some hydraulic erosion if the field is drained soon after the roller passes, when still there are suspended sediment in water. The best management practice on this sense is the particles sedimentation before opening the drainage water. Depending on the soil type, the saturated soil tillage leads to the formation of surface crust, which has implications for the seedbank germination. The crust reduces the emergence in winter, whereas can create difficulties in the sowing process, e.g. for winter pasture with small seeds, as the Italian ryegrass (Loliummultiflorum). It was observed that using a disc harrow over soil crust in order to break up the hardness ensures the crop establishment and the initial growth. The presence of large clods restricts soil-seed contact and thereby decreases the germination rate, as pastures or spontaneous weeds.

When the roller is employed after rice harvest for straw incorporation and soil leveling, the cattle could be introduced in the area only 60 days after harvested at some situations. Field studies during the 2009/ 2010 integrated crop livestock production resulted in indication that using knife roller to soil tillage after rice crop could give, for the continuous grazing with initial stocking density of 0.71heifers ha^{-1} (heifer @ 450kg and cross with British races) and forage dry mass of 1,600kg ha^{-1} (ryegrass, white clover and birdsfoot trefoil), a gain of 426kg ha^{-1} at the end of a cycle in the summer without any feed supplementation, after 245 days. This has led to almost an increase of five times the weight gain compared with traditional model, using a seed spreader to sowing ryegrass on the rice harvested area.

4. Conclusion

In this paper, is presented a method for soil adjustment after the harvest of rice in irrigated fields and different components of rice production systems were discussed. A heavy knife roller can be used in just harvested rice fields to provide an early land preparation. It is shown that the roller can be operated during a rainy season, when the condition of soil saturation soil is a restriction to conventional tillage machinery, and the land preparation delays the next crop sowing schedule, which may decrease the production yield. Using the knife roller in adequate conditions is possible - with a single one-pass of machinery over the field leveling the rice ratoon and straw, the soil and the bunds across the field and eliminate the tracks of machinery, soon after the rice harvest. According to the experimental results over controlled conditions and at a farmland level, the soil autumn prepared with the roller showed lesser weed infestation in the summer; and optimization of labor and machinery timetable, once the roller is an alternative to the use of plow and harrow. In addition, lower fuel consumption compared with traditional tillage methods (harrowing and land leveling) make the roller economically feasible to be implemented by farmers. There is a strong interest within the local householders for a livestock production as a land leasing in the intercrop period. Adoption of crop-livestock production systems, in particular, with knife roller in order to incorporate rice straw into the soil and land leveling, seems to be a much better way of establish a winter pasture and improved the overall system performance than purely put pasturing animals on rice ratoon area.

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6. References

ANDRES, A. CONCENÇO, G., THEISEN, G., GALON, L., & TESIO, F. Management of red rice (Oryza Sativa) and Barnyardgrass (Echinochloa Crus-Galli) grown with sorghum with reduced rate of atrazine and mechanical methods. *Expl. Agric.*, 48, 4, 587-596, 2012.

BHAGAT, R.M., BHUIYAN, S.I., & MOODY, K. Water, tillage and weed interactions in lowland tropical rice: a review. Agric. *Water Manag.*, 31, 165-184, 1996.

BHATTACHARYYA, R., KUNDU, S., PANDEY, S.C., SINGH, K.P., & GUPTA, H.S. Tillage and irrigation effects on crop yields and soil proprieties under rice-wheat system in the Indian Himalayas. *Agric. Water Manag.*, 95, 993-1002, 2008.

CANALI, S., CAMPANELLI, G., CIACCIA, C., LETEO, F., TESTANI, E., & MONTEMURRO, F. Conservation tillage strategy based on the roller crimper technology for weed control in Mediterranean vegetable organic cropping systems.

Europ. J. Agronomy, 50, 11-18, 2013.

EDMINSTER, T.W., MILLER Jr, H.F., & NORMAN, A.G. Recent developments in agricultural machinery. *Adv. Agron.*, 11, 171-232, 1959.

FAGERIA, N.K., SLATON, N.A., & BALIGAR, V.C. Nutrient management for improving lowland rice productivity and sustainability. *Adv. Agron.*, 80, 63-152, 2003.

LUNA, J.M., MITCHELL, J.P., & SHRESTHA, A. Conservation tillage for organic agriculture: evolution toward hybrid systems in the western USA. *Renew. Agric. Food Syst.*, 27, 1, 21-30, 2012.

MORRIS, N.L., MILLER, P.C.H., ORSON, J.H., & FROUD-WILLIAMS, R.J. The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and environment - a review. *Soil Tillage Res.*, 108, 1-15, 2010.

RAHMAN, M.A., CHIKUSHI, J., SAIFIZZAMAN, M., & LAUREN, J.G. Rice straw mulching and nitrogen response of no-till wheat following rice in Bangladesh. *Field Crops Res.*, 91, 71-81, 2005.

RAO, A.N., JOHNSON, D.E., SIVAPRASAD, B., LADHA, J.K., & MORTIMER, A.M. Weed management in direct-seeded rice. *Adv. Agron.*, 93, 153-255, 2007.

RODENBURG, J., SAITO, K., KAKAI, R.G., TOURÉ, A., MARIKO, M., & KIEPE, P. Weed competitiveness of the lowland rice varieties of NERICA in the southern Guinea Savanna. *Field Crops Res.*, 114, 411-418, 2009.

SANUSAN, S., POLTHANEE, A., AUDEBERT, A., SERIPONG, S., & MOURET, J.C. Suppressing weeds in direct-seeded lowland rainfed rice: effect of cutting dates and timing of fertilizer application. *Crop Prot.*, 29, 927-935, 2010.

SINGH, G., JALOTA, S.K., & SINGH, Y. Manuring and residue management effects on physical properties of a soil under the rice-wheat system in Punjab, India. *Soil Tillage Res.*, 94, 229-238, 2007.

SUDIANTO, E., BENG-KAH, S., TING-XIANG, N., SALDAIN, N.E., Scott, R.C., & BURGOS, N.R. Clearfield rice: its development, success, and key challenges on a global perspective. *Crop Protection*, 49, 40-51, 2013.

VALSESIA, M., BISAGLIA, C., BOCCHI, S., & BORDIGNON, L. Tecniche di coltivazione del riso a basso impatto ambientale: riso secondo natura. In ed. Aerre, Gaglianico (in Italian), 2009.

WHITBREAD, A., BLAIR, G., KONBOON, Y., LEFROY, R., & NAKLANG, K. Managing crop residues, fertilizers and leaf litters to improve soil C, nutrient balances, and the grain yield of rice and wheat cropping systems in Thailand and Australia. *Agric. Ecosyst. Environ.*, 100, 251-263, 2003.