Study on permanent-bed-planting with double zero tillage for rice and wheat in Sichuan Basin

Yonglu Tang, Jiaguo Zheng, Gang Huang and Jinquan Du

Crop Research Institute, Sichuan Academy of Agric. Sci., Chengdu, China, 610066. Email tylu88@hotmail.com

Abstract

Throughout the formal experiments at selected locations and comparison trials conducted in the same fields from 1993 to 1997, the technique of permanent-bed-planting with double zero tillage for rice and wheat (PBDZ) was investigated. The aim was to determine the influence on the yield of rice and wheat and the pattern of production trends, to determine the factors increasing yield for both rice and wheat and to evaluate economic benefits. The results show that the PBDZ can significantly increase rice and wheat yield. Compared with the traditional cropping technique (TCT), wheat yield increased by 6.7%~9.7%, and rice yield by 5.1~6.7%. The yield increase for wheat was more than for rice, and the wheat yield showed an increasing trend over years, while the rice yield increase showed a gradual declining pattern. The substance cost of PBDZ was reduced by 1290 Yuan/ha compared to TCT, while labor cost was reduced by 645 Yuan/ha. In addition to the yield and income increase of 847 Yuan/ha, the annual saving in costs and the increase in income all together amount to 2782 Yuan/ha, i.e. 76% increase over the traditional practice. The increase in yield of rice and wheat with the PBDZ technique can be accounted for by changes in pedology, agronomy and physiological ecology of the new cropping technique.

Media summary

A new cropping technique designated as permanent-bed-planting with double zero tillage for rice and wheat will boost yields and profit in Sichuan province of China.

Keywords

Permanent-bed-planting, Double zero tillage, Yield, Profit

Introduction

The majority of the rice-wheat cropping system in Sichuan is concentrated on the hilly area and the surrounding mountains. Due to the reasons of topology and climate, there exist the problems of sticky, clay type soil, difficulty for water infiltration, and difficulty of plowing and preparing soil prior to planting. The present prevailing traditional cropping practice of plowing and preparing the field each season is not only labor intensive and difficult to operate, but also not favorable for high yield of rice and wheat, and for soil improvement.

Since 1984 the zero tillage research on rice and wheat has been conducted in accordance with the characteristics of the rice-wheat cropping system in Sichuan Basin. In the actual application, generally the practice of zero tillage for one crop followed by tillage for the next crop is practiced. The more popular approaches are rotovator plowing of the paddy field followed by wheat zero tillage, or paddy zero tillage followed by rotovator plowing for wheat. Since 1990’s, as social economic conditions further developed, there was a dramatic change of rural fuel practice in that the large quantity of crop residues are no longer removed and used as fuels but are simply discarded. Meanwhile, the rural laborers have been migrating to other areas and thus the cost of labor is increasing. Consequently, there is a growing demand for simplified cultivation techniques. Therefore, we have conducted a series of experiments on the technique of permanent-bed-planting with double zero tillage for rice and wheat (abbreviated as PBDZ), in order to increase yield and efficiency and to promote sustainability. In this paper, we report the results of comparing these technologies since 1993.

Methods

From 1993 to 1997, the experiment was selected and conducted in Meishan county, Sichuan province. The soil was a heavy clay with low fertility. After wheat harvest and before the initiation of the experiment in 1992, the soil was tested. Two treatments were included: One was the permanent-bed-planting with doubling zero tillage for rice and wheat (PBDZ), and the other was the traditional cropping technique (TCT). PBDZ: 3.0m for the bed width, 0.25m for ditch depth between the beds, 0.3 m for ditch width. For wheat crop, simple sowing machine (2BJ-2) was used to sow the seed on the surface of the soil, with spacing of 20cm by 10cm. After sowing, all the previously harvested rice straw was returned to the field as mulch. For the rice crop, after wheat harvest, the beds and ditches were repaired, and all the harvested wheat straw was placed in the ditches, seedlings were broadcast into the zero tilled paddy field for establishment, with spacing adjusted to 25cm by 15cm. The bed surface was kept moist rather than with standing water during broadcasting the plants. Afterwards, the ditches were filled with water and the surface of the beds was kept moist with shallow water. TCT: for wheat, after ploughing and harrowing the soil, seed was dibble planted in holes with spacing of 30cm by 15cm, without rice straw mulching. For rice, after ploughing and irrigating the whole field, manual transplanting was conducted. The plant spacing, fertilization and field management was the same as for the PBDZ treatment. The plot size was $360m^2$ for all the treatments and there were three replications.

Results

1. Effects of yield increases in rice and wheat and their changing pattern with time

A number of comparison trials and demonstration trials in different ecological regions were analysed. The PBDZ technique had higher wheat yields with an average increase of 6.7%~9.7% when compared with TCT in newly drained winter water reserved fields and in wide mid- and low yielding wheat growing areas, especially in wet autumn years. For the bottom wet clay fields and a slush field, the yield increase was larger, generally by 10%~20%. The rice yield was increased by an average of 5.1%~6.7%, and in the drier regions, the yield increase reached around 10%.

The results of the comparison of planting methods over the five-year formal experiments (Table 1) showed that the wheat yield increased by 6.7% and rice by 5.1% in PBDZ. Yield increase was greater in wheat than in rice, and the wheat yield increased year by year, while the trends in rice yield was more variable.

Table 1. The yield comparisons between the ways of long term zero tillage and traditional cropping (1993-97; kg/ha)

Crop	Treatment	1993	1994	1995	1996	1997
Wheat	PBDZ	5587.5	5470.5	5949.0	5757.0	5853.0
	TCT	5314.5	5182.5	5556.0	5344.5	5410.5
	?%	5.1	5.6	7.1	7.7	8.2
Rice	PBDZ	7320.0	8014.5	7246.5	7518.0	8115.0
	TCT	6676.5	7459.5	6976.5	7282.5	7776.0
	?%	9.6	7.5	3.9	3.2	4.4

2. Analysis of economic benefits for the PBDZ

PBDZ technique can make savings in two major work activities that is required in normal rice production, i.e. preparing the field and manual transplanting, and can simplify the procedures of land preparation and sowing for wheat. This greatly reduces the substance cost and labor cost for the rice and wheat cropping system. According to our detailed statistics, the substance cost of PBDZ was reduced by 1290 Yuan/ha compared to TCT, labor cost was reduced by 645 Yuan/ha, and the total cost was reduced by 19%. As a result, the annual additional income reached 2782.5 Yuan/ha (76%). The income rate for material cost (IRMC) of the PBDZ technique was 2.45 Yuan/Yuan, the increased net income rate (INIR) was 0.758 Yuan/Yuan, the income rate for capital cost (IRCC) was 1.78 Yuan/Yuan, and the marginal income for rate of cost (MIRC) was -0.438 Yuan/Yuan. The capital use of the economic benefit and relative economic benefit of the new cropping model were significantly improved (Table 2).

Table 2. The comparison of the economic benefit for the different cropping models

Crop	Tr.	MC	LC	TC	TOV	NR	IRMC	IRCC	INIR	MIRC
Rice	PBDZ	1875	2400	4275	8407.5	4132.5	3.20	1.97	0.570	-0.429
	TCT	2475	2850	5325	7957.5	2632.5	2.06	1.49	/	/
Wheat	PBDZ	2565	1410	3975	6295.5	2320.5	1.90	1.58	1.240	-0.449
	TCT	3255	1605	4860	5898.0	1038.0	1.32	1.21	/	/
Total	PBDZ	4440	3810	8250	14703.0	6453.0	2.45	1.78	0.758	-0.438
	TCT	5730	4455	10185	13855.5	3670.5	1.64	1.36	/	/

Note: MC-material cost, LC-labor cost, TC-total cost, TOV-total output value, NR-net receipt, IRMC-income rate for material cost, IRCC-income rate for cost capital, INIR-increased net income rate, MIRC-marginal income rate for cost. The average price of rice or wheat is 1.10 Yuan per kg; the TOV is the average of 5 years. The unit in table is Yuan/ha.

3. Mechanism of yield increase for wheat.

PBDZ-wheat emerged faster, tillered earlier, produced more bud sheath tillers and lower tillering nodes, and more node roots, all of which facilitate stronger plants. Zero tillage does not disturb soil layers but keeps soil intact with good soil capillarity and porosity. This avoids excessive soil wetness that makes soil sticky and compact, and improved soil structure in the surface layer when compared to TCT. The straw mulch had a substantial effect on soil temperature and evaporation. The surface soil moisture was apparently improved in comparison with TCT, thus improving drought resistance.

The number of secondary roots, the total root length per plant and the root weight of surface seedlings were all greater in PBDZ than in TCT. During the jointing period, the average number of roots per plant was 24.6, being 5.4 more than TCT. At maturing period, the average number of roots reached 47.0 in PBDZ, being 17.0 more than in TCT. The average root length at jointing stage was larger for PBDZ than TCT treatment, while it was reversed later. However, because there was a stronger rooting system in PBDZ and hence more roots produced, their average total length or length per plant was much larger in PBDZ. At jointing stage, PBDZ-wheat has total root length of 171cm per plant, 60% more than TCT treatment, and 23% more at maturing stage. The average root weight per plant was 44% higher in PBDZ than TCT during jointing stage, and 51% more in the maturing stage.

The PBDZ-wheat enhanced early tillering and tillering potential. The initiation of tillering was generally advanced by 2 to 3 days, and the tillers per plant increased by 3.7% compared to TCT. The tillering at the bud sheath stage reached 18.9%, being 16.4% more than TCT treatment It also increased plant tillering percentage and bud sheath percentage by 3.5% and 13.1% higher than TCT. PBDZ-wheat had plants and tillers of 529/m^2 at the tillering period, 18% higher than TCT, and the tillers per plant were 1.2, 15.0% higher. PBDZ-wheat had plants and tillers of 788/m^2, 32% higher than TCT and, had 2.2 tillers per plant, 34% higher. Especially important, during the jointing stage was the number of tillers per plant as tillers can either develop or abort after this stage. PBDZ-wheat had 1.86 tillers per plant, being 31% higher than TCT, 69% of the tillers having 4 or more leaves, while TCT had only 41%. Apparently, PBDZ-wheat had earlier, stronger, larger and more tillers and earlier developing plants, which facilitated the number of ears. The PBDZ-wheat was 2.1~4.3 cm taller than TCT, but with the first and second basal nodes apparently shortened, and the upper internodes and particularly ear- nodes elongated. These shortened basal internodes, and elongated ear- nodes favor lodging resistance and economic yield.

4. Mechanism of yield increase for rice

The DZPB-rice had a higher number of stems and tillers than TCT, and reached the maximum number 7 days earlier. After the maximum tillering stage, the tillers of PBDZ-rice were reduced much faster than those in TCT. However, the final panicle density was still higher in the PBDZ than TCT. The growth vigor can be expressed in the dry matter weight, LAI and photosynthetic potential. At the maximum tillering period, PBDZ-rice plants had a 19% higher dry matter than TCT and 2.1% higher leaf area index (LAI). At the end of the panicle initiation period, PBDZ-rice was 59% heavier than TCT, had a 2.9% larger LAI and at the milking stage, the former two parameters were 34% and 4.2% higher respectively. From the maximum tillering to panicle initiation stage, the photosynthesis potential of PBDZ-rice was 35% higher than TCT, while from the end of panicle initiation to maturity it was 48% higher. PBDZ-rice had shorter internodes with elongated upper internodes that facilitated resistance to lodging. It was observed that in the years of 1994, 1996 and 1997 when lodging occurred, it was less severe in PBDZ-rice than in TCT-rice.

PBDZ-rice had stronger translocation ability than TCT-rice, which promotes panicle development. C^{14} was applied during the maturing period and it was tested 96 hours after it was applied and the C^{14} in the ears, stems and roots was measured. It showed that 83% of the photosynthetic products were transported into the ears in PBDZ plants 12% higher than TCT. Translocation into roots was 10% for PBDZ while it was 8.5% for TCT. The CO_2 fixed per hour was 0.108 mg for PBDZ while it was 0.097 mg for TCT.

Conclusion

PBDZ increases production through changes in the areas of pedology, agronomy and physiology. In terms of wheat, it can avoid rough seeding conditions, hence promoting good sowing conditions. It reduces soil wetness, weeds and lodging, and promotes tillering and number of ears, hence resulting in higher yield. In terms of rice, it can effectively improve sowing conditions and reduce poor rice growth. It promotes tillering, growth and vigor, photosynthate production and translocation, and reduces disease and leads to higher yield. PBDZ largely eliminates the traditional procedures of ploughing and sowing, and reduces labor demand. It enhances cropping through reducing production costs and increasing yield. Furthermore, it has the advantage of protecting the environment and improving sustainability. A large quantity of straw is returned to the field which will improve soil fertility, lessen crop residue burning and protect the environment, as well as enhancing drainage and drought resistance, restrain weed and reduce herbicide use.

References

Griffith DR, Kladivko EJ, *et al*.(1988). Long-term tillage and rotation effects on corn growth and yield on high and low organic matter, poorly drained soil. Agron.J. 80, 599-605.

Norwood, C(1988).Conservation tillage cropping systems; Southwest Kansas Experiment Station.In “Conservation tillage research”,Kansas State Univ. AES Report of Progress 542,1-9.

Eghball, B, Mielke, LN, Calvo, G.A(1993). Fractal description of soil fragmention for various tillage methods and crop sequences. Soil Sci, Soc. Am.J. 57, 1337-1341.

Limon, A.O, Sayre, K.D. and Francis, C.A.(2000). Wheat and Maize Yields in Response to Straw Management and Nitrogen under a Bed Planting System. Agron.J.92, 295-302.

Yonglu T, Gang H, Lixun Y, *et al*.(2002). Studies on the technology of surface seeding and multching straw for wheat after rice. Southwest China Journal of Agricultural Sciences. 15, 32-37.