



## The System of Wheat Intensification (SWI)

Initial Test by Farmers

in Goundam and Dire, Timbuktu, Mali 2009

Erika Styger and Harouna Ibrahim

for the Timbuktu Food Security Initiative (TFSI)

September 9, 2009





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## Summary

The System of Wheat Intensification, or SWI, is an adaptation of techniques used in the System of Rice Intensification (SRI). SRI, successfully practiced in over 35 countries, gave increased paddy yields of 66-87% for 60 farmers in the Goundam and Dire circles of the Timbuktu region in Mali in 2008/2009. Based on these positive results, three village leaders from that area, who are among the SRI pioneer farmers, discussed running a small test with Africare technicians, to apply the SRI principals to their off-season crop wheat. Three treatments were chosen: SWI direct seeding, SWI with the transplanting of seedlings and the control plot based on seed broadcasting. Each plot measured 100 m<sup>2</sup>. We adopted the same crop management practices as applied under SRI during the 2008/2009 cropping season: i) application of organic matter at 10-15 tons/ha, ii) incorporation of organic matter into the soil through tilling, followed by a good land leveling, iii) planting one plant/pocket using 25 cm x 25 cm spacing in a square pattern (Treatment 1: direct seeding with in-field germination; Treatment 2: transplanting of seedlings at the 2-leaf stage), iv) use of a cono-weeder several times immediately after irrigation, and v) reduced irrigation water during the vegetative growth period.

Wheat yield for SWI direct seeded (SWI DS) was 2.2 t/ha, or 13% higher compared to the control, which obtained 1.97 t/ha. Transplanted SWI (SWI TR) showed a 29% yield decline over the control with 1.4t/ha. These yield levels were slightly below the regional yield average of 2.4t/ha for 2009. We attribute these lower yields to the late planting of the crop, under which wheat maturation coincided with the hot winds and rising temperatures. Other yield reducing factors for SWI were i) the 25cm x 25cm spacing was too wide, and left much empty space between plants, and ii) a mortality rate of 22% for SWI DS, and of 9% for SWI TR.

On the other hand, yield parameters of SWI were superior to the control: the number of tillers/plant (18.4 for SWI SD vs. 3.7 for Control), number of panicle/plant (17.7 vs. 2.7), % of fertile tillers (96 vs. 73), panicle length (10.2cm vs. 4.2cm), number of grains/panicle (58 vs. 35), and the thousand grain weight (28.1g vs. 21.1g). The SWI TR performance was slightly inferior for all yield parameters to SWI SD but higher than the control. As transplanting is a novelty in the region, these results should be confirmed or reconsidered through proposed modifications from this first SWI experience.

Significant improvement with SWI was obtained in labor and water productivity. Labor requirement for SWI was reduced by 35-40% compared to the control. The return to labor (wheat produced per unit of labor) under SWI SD increased by 74% over the control. In addition, the amount of irrigation water used was reduced by 25-30% under SWI compared to the control, which is of great importance to the region, where water limitations present a major constraint.

In conclusion, despite the limited yield increases in this first year, labor and water productivity have already shown significant improvements over the conventional system. Nevertheless, there seems to be much potential for significantly increasing yields levels, by developing better direct-seeding techniques, reduce the spacing between plants, and by targeting the optimal planting time.

## 1. Introduction

The System of Wheat Intensification, or SWI, is an adaptation of techniques used in the System of Rice Intensification (SRI). SRI, successfully practiced in over 35 countries, gave increased paddy yields of 66-87% for 60 farmers in the Goundam and Dire circles of the Timbuktu region in Mali in 2008/2009. (See text box on page 2).

Farmers in the Goundam and Dire circles cultivate rice during the main growing season in small-scale, village-based irrigation schemes --*Périmètres Irrigués Villageois (PIVs)*-- most often 30-35 ha in size. During the cooler dry season, wheat, anise, and cumin are cultivated as cash crops. Farmers sell some of the wheat they produce, but also make their own bread with it.

Wheat has been cultivated in this area for centuries. In the past, plots were watered by hand, using calabashes. About 30 years ago, with the introduction of the PIVs, the irrigation system changed, relying on diesel motor-pumps for irrigation. This change allowed for an increase in the area under cultivation, and wheat evolved from a subsistence crop to a cash crop.

Today, 94 % of the wheat produced in the Timbuktu region is grown in the Goundam and Dire circles. In 2009, a total of 3,865 hectares was cultivated in Timbuktu with an average yield of 2.4 t/ha (see Table 1). Yields in the region vary from 2 to 3 tons/ha. Government agriculture service staff in the region report yields of 4-5 t/ha, when their technical recommendations are adopted. Nevertheless, our three SWI farmers informed that their top yields to date have never exceeded 3.5 t/ha.

Table 1: Wheat production in the Timbuktu region in 2009

Circle	Surface ha	Yields t/ha	Production t
Timbuktu	26	2.1	55
Niafunke	30	1.9	57
Goundam	1406	2.6	3656
Dire	2243	2.9	6505
Rharous	160	2.5	400
Total	3865		10672
Average		2.4	

(DRA Timbuktu, 2009)

## What is SRI?

SRI is a methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients while reducing external inputs.

SRI is based on 6 principles:

1. Transplanting single seedlings
2. Transplanting seedlings at the 2-leaf stage (8-12 days old)
3. Wide spacing between plants, 25cm x 25 cm or wider, transplanting in a square pattern
4. Minimum water application during vegetative growth, keeping soils moist but well-drained and aerated
5. Frequent weeding with a simple mechanical hand weeder
6. Application of organic matter at 10-15t/ha, in preference to chemical fertilizer

### Results from 60 SRI farmers in Goundam and Dire, 2008/2009

- Average yield of 9.1 t/ha, with the lowest yield being 5.4 t/ha and the highest 12.4 t/ha, representing a yield increase of 66-87% over adjacent rice fields.
- Reduction in amount of seeds used by 85%-90% from 40-60kg/ha used traditionally to 6.1kg/ha used by SRI farmers
- Reduction of 30% chemical fertilizers
- Reduction in irrigation water by 10%
- Reduction of production costs per kg of paddy: 30%
- Increase of income per hectare: more than doubled

### For more information on SRI in Timbuktu

Website links:

- SRI: Community-based evaluation in Goundam and Dire, Timbuktu, 2008/2009; Report in English: <http://ciifad.cornell.edu/sri/countries/mali/MaliAfricare%2008and09.pdf>
- Report in French: <http://ciifad.cornell.edu/sri/countries/mali/MaliAfricare08and09Fr.pdf>
- Fiche Technique: [http://ciifad.cornell.edu/sri/countries/mali/Mali\\_SRI\\_Fiche\\_Technique09.pdf](http://ciifad.cornell.edu/sri/countries/mali/Mali_SRI_Fiche_Technique09.pdf)
- SRI Timbuktu Blog: [http://www.erikastyger.com/SRI\\_Timbuktu\\_Blog/SRI\\_Timbuktu\\_Blog.html](http://www.erikastyger.com/SRI_Timbuktu_Blog/SRI_Timbuktu_Blog.html)
- SRI Information at Global Level: <http://ciifad.cornell.edu/sri/>

To date, efforts to improve wheat cultivation systems in the Timbuktu region have focused on the introduction of short-cycle varieties and the use of chemical fertilizers. Crop management and cultivation practices have shown little change, at least within memory of farmers in the region, and remain largely traditional. Crop establishment, for example, is still based on seed broadcasting. Farmers use from 100 to 140kg of seed per hectare. Fields are prepared with superficial tillage. Plots are delimited, and small dykes are established around each plot to retain irrigation water. Farmers then broadcast the seed onto dry soil, and subsequently cover the seed with soil brought in from elsewhere.

In former times, farmers broke up termite mounds, a source of enriched soil, and transported this soil to the wheat fields to cover the broadcast seeds. This old practice is still maintained today, although the termite mounds have practically disappeared. Today, farmers dig soil from around dead tree roots instead, because this soil has a superior quality compared to other soils. Nevertheless, given the amounts needed, most farmers must also take good topsoil from locations close to their wheat fields. These practices, if repeated each year, degrade the environment surrounding the agricultural fields.

The first irrigation is done once the broadcast seeds have been covered with soil. Immediately following, the newly exposed seeds are further covered with new soil. This procedure continues over a period of 15 days, during the rather irregular germination of the crop, and requires much labor.

Reasons given for this soil application are: i) it covers the seeds for better germination, ii) it protects seeds from granivorous birds, iii) it fertilizes the fields, and iv) it improves the soil structure. This traditional fertilization technique remains from a time before the use of manure or chemical fertilizers.

At present, farmers use about 100 kg/ha of phosphorus fertilizer in the beginning of the season and about 100kg/ha of urea, which is less than the recommended amount. Crops are weeded by hand, and irrigation is done carefully, paying attention to the wheat crops' intolerance for flooding.

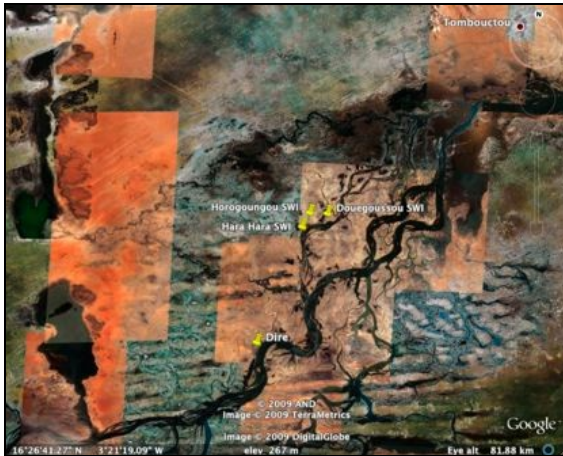
The idea to adapt SRI principles (see SRI Box) to growing the wheat crop emerged from discussions between SRI farmers and Africare staff. The leaders of three villages, who are among the SRI pioneers in the Timbuktu region, took the initiative for this first-time test of the System of Wheat Intensification by applying a nearly identical technical protocol as for SRI rice. See their photos at the end of this report.



## 2. Methodology

### 2.1. Location

This test was undertaken by village leaders of Horogoungou and Hara Hara (both in the Dire circle) and Douegoussou (Goundam circle), all neighboring villages that pioneered SRI evaluation in 2007 and 2008. The location of these three villages in respect to the Niger River, Timbuktu town and Dire town is shown in these satellite maps.



Horogoungou, Hara Hara and Douegoussou, located on a river branch of the Niger River (which runs from lower left corner to upper right corner). Note the location of Dire (on the Niger) and Timbuktu (right upper corner of the picture)



GPS location of SWI fields 2009 of the three SWI villages located along the same river branch of the Niger River

### 2.2. Treatments

Three treatments were implemented on plots sizes of 100 m<sup>2</sup>:

- 1) SWI – established through Direct Seeding = SWI DS
- 2) SWI – plants raised in nursery and Transplanted at the two-leaf stage = SWI TR
- 3) Control – current practice of seed broadcasting

In this test, we adopted the same crop management practices as applied to SRI rice during the 2008/2009 cropping season. These include:

- Application of organic matter at 10-15 tons/ha,
- Plowing of the soil and good land leveling
- Planting one plant/pocket in lines, with 25 cm x 25 cm spacing (Treatment 1: direct seeding with in-field germination; Treatment 2: transplanting of seedlings at the two-leaf stage)
- Use of cono-weeder, several times immediately after each irrigation
- Reduced irrigation water during the vegetative growth period

Details of the three treatments are presented in the following table:

Table 2: Methodology of SWI and control treatments

	<b>SWI – Direct Seeded</b>	<b>SWI – Transplanted</b>	<b>Control</b>
Seeding (3 villages)	23Dec, 24Dec, 2Jan	23Dec, 24Dec, 2Jan	23Dec, 24Dec, 2Jan
Harvest (3 villages)	1, 2, 3 April	1, 2, 3 April	1, 2, 3 April
Cycle (3 villages)	91, 99, 99 days	91, 99, 99 days	91, 99, 99 days
Wheat Variety	Tetra	Tetra	Tetra
Land preparation	Plowing	Plowing	Plowing
Crop establishment	Direct seeded in pockets	Nursery	Seed broadcast
Seed treatment	Soaking 24h	Soaking 24h	None
Seed bed	Moist/Dry	Moist	Dry
Plants/pocket	1 seed	1 plant	-
Plant spacing	25cm x 25cm	25cm x 25cm	-
Age of transplanting	-	18 days (11-28 d)	-
Number of leaves/plant	-	3 (2-4)	-
Seeds used	8.5 kg/ha	13.5 kg/ha	176 kg/ha
Manure application	13 t/ha	13t/ha	Topsoil
Urea (kg/ha)	75 kg	75 kg	75 kg

### 2.3. Cropping calendar and cycle

Plots were established late December and early January when farmers installed their wheat perimeters. Harvest was done in early April. All three farmers used the same variety, Tetra, which has a cycle of 91 to 99 days.

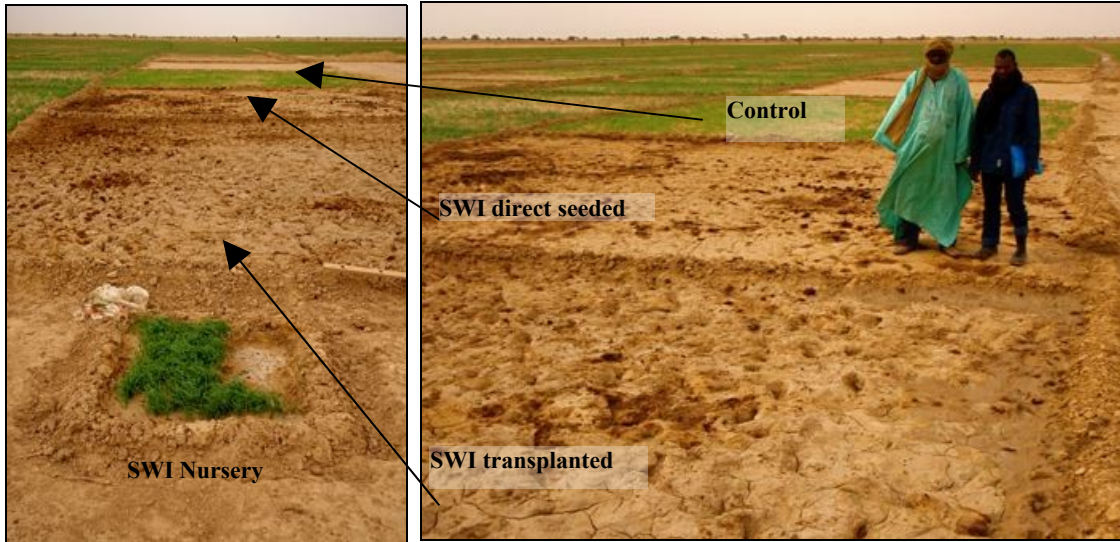
### 2.4. Establishment of the treatments

For both SWI treatments, manure was applied at 10 –15 t/ha with an average of 13 t/ha for the three villages. Manure was incorporated into the soil with a superficial tillage. The dry soil was leveled after breaking up the soil chunks. Seeds were soaked for 24 hours prior to seeding. For the direct seeding treatment, the first irrigation was done in one village before seeding, so that soil conditions were moist when seeded. In two villages, irrigation was done after seeding, thus seeding was done into dry soil. One seed/pocket was sown with a spacing of 25 cm x 25 cm between pockets. For the transplanting treatment, the first irrigation was done before field leveling, transplanting was done with one plant/pocket, with a spacing of 25cm x 25cm between pockets, and from 11 to 28 days after nursery establishment, when plants had from 2 to 4 leaves.



Remaining plants in SWI nursery, 14 days after seeding (SWI was transplanted at 11 days) in Horogoungou

For the control, seeds were broadcast onto dry soil after plowing. Manure was not applied, but conforming to traditional practice, topsoil collected from outside the plot was used to cover the seeds. Once covered, the first irrigation of the plot was done, followed by another application of topsoil to cover the freshly exposed seeds. Seeds were sown without any prior treatment.



Two views of the SWI test in Horogoungou: three 10m x 10m plots: In the foreground, the SWI transplanted plot (3 days after transplanting); in the middle (where two persons are standing) the SWI direct-seeded plot; and in the rear, the control plot. Control and SWI direct-seeded plots at 14 days after seeding. Note that the SWI plants are barely visible at this stage.



Broadcast control plot in Horogoungou, 14 days after seeding – irregular germination

SWI direct seeding treatment, 14 days after seeding

## 2.5. Amount of seed used

The usual farmer practice is to use about 100-140 kg of seed per hectare. In our trial, a bit more was used, 176 kg/ha for the control plot. The SWI treatments used only 5% - 7.5% of this amount, from 8.5 - 13.5 kg/ha.

## **2.6. Fertilization**

In the SWI plots, manure was applied at 13 t/ha on average. In the control plots, farmers applied topsoil to the plot four times. Soil was applied before the first irrigation, then immediately after the first irrigation, and then twice from one to three weeks after the first irrigation. In addition, farmers also applied 75 kg/ha of urea to all three treatments at the time of tillering.

## **2.7. Experimental management and harvest methodology**

SWI farmers and the Africare technician assured experimental management and collected data on technical parameters and on labor. We used the same harvest procedures for each plot as with last years' SRI plots: Three squares of 4 m<sup>2</sup> each were harvested for each treatment, threshed on location, and weighed with moisture content determined with the FARMEX MT-PRO™ moisture meter. The field yield results were then adjusted to the wheat standard for reporting yield with 13% grain moisture content. We counted the number of tillers in three 1 m<sup>2</sup> squares for each treatment. Six panicles were randomly selected per treatment, and panicle length was measured. Through destructive measures, the number of grains was counted per panicle. The results reported in this report are the average numbers from the three sites.

### 3. Results

The results presented include yield and yield parameters, aspects on weeding and irrigation, and some considerations on labor.

#### 3.1. Wheat yields and yield parameters

Table 3: Wheat grain yield and yield parameters in SWI direct-seeded, SWI transplanted treatments, and the control (reported at 13% grain moisture content, average of three villages)

<b>Parameters</b>	<b>Units</b>	<b>SWI Direct Seeded</b>	<b>Dir- Seeded</b>	<b>SWI Trans- planted</b>	<b>Control</b>
Yield *	t/ha	2.22		1.4	1.97
Mortality	%	22		9	-
Tillers/plant	Number	18.4		13.1	3.7
Panicles/plant	Number	17.7		9.9	2.7
Fertile tillers	%	96		76	73
Panicle length	cm	10.2		8.4	4.2
Grains/panicle	Number	58		42	35
Plants/m <sup>2</sup>	Number	12.4		14.5	92
Panicles/m <sup>2</sup>	Number	219		144	248
1000 grain weight	g	28.1		27.0	21.1

\* Calculated to 13% grain moisture

Wheat yield for direct seeded SWI (SWI DS) was 2.2 t/ha, compared to 1.97 t/ha in the control, and 1.4 t/ha in the transplanted SWI (SWI TR). SWI DS had a 13% yield increase over the control, whereas SWI TR showed a 29% yield decline compared to the control. Wheat yields in the region vary from 2 to 3 tons/ha. Yield average for the Timbuktu region was 2.4 t/ha in 2009. Our test results correspond therefore to lower to medium yield levels for the region as a whole.

Mortality rate of SWI direct seeding treatment was 22%, compared to 9% for the SWI transplanted treatment. When direct-seeded in moist (pre-irrigated) soil, plant mortality was only 11% compared to 28% when seeded into dry soil. For the control, mortality rate was not determined. With the very densely-seeded plots and extended germination periods over 2 weeks, this would have been a difficult undertaking for this first test.

Tillering: SWI plants tillered remarkably higher compared to the control plants. At harvest, average number of tillers was 18.4 for SWI DS and a bit lower for SWI TR with 13.1. It was much lower for the control with only 3.7 tillers/plant.



SWI plant      Control plant

At harvest, SWI direct seeded plants averaged at 18.4 tillers/plant compared to 3.7 tillers/plant for the control

Agaly Alhassane, SRI farmer from last season (village of Horogoungou), comes and checks out the SWI plots

At flowering, the average number of tillers per SWI SD plants was 33, for SWI TR it was 19.5 and for the control 4.4. Figure 1 shows how numbers of tillers increased over the cropping cycle, and subsequently declined after flowering.

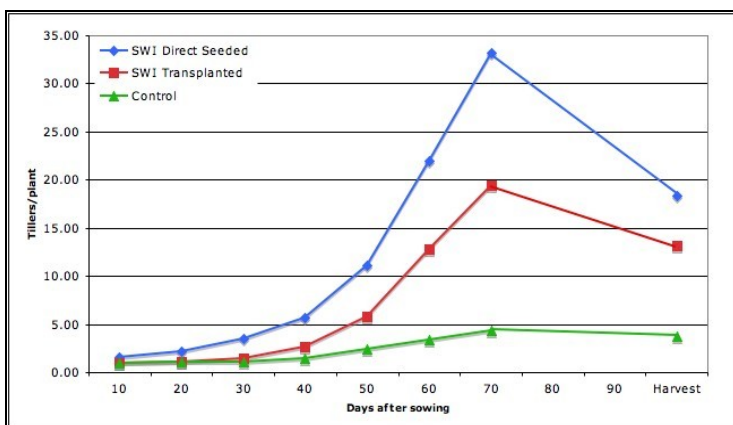


Figure 1: Evolution of tiller numbers for SWI and control plots in three villages in 2009

SWI plant in Horogoungou at 50 days after seeding. Largest tiller increase occurred from 50 days to 70 days.

Initially, the wheat showed a slow tiller increase; greater increase happened only after 40 days, with the strongest tillering increases occurring from 50 to 70 days after seeding for both SWI treatments. New tillers formed up to the time of flowering and grain-filling of older panicles. Some of the small non-fertile tillers were then re-absorbed after flowering began at 70 days, which explains the decrease in tiller numbers after 70 days.

Fertile tillers: Percentage of fertile tillers (number of tillers with panicles/total number of tillers) was 96% for SWI SD, whereas for SWI TR and the control it was significantly lower with 76% and 73%, respectively.

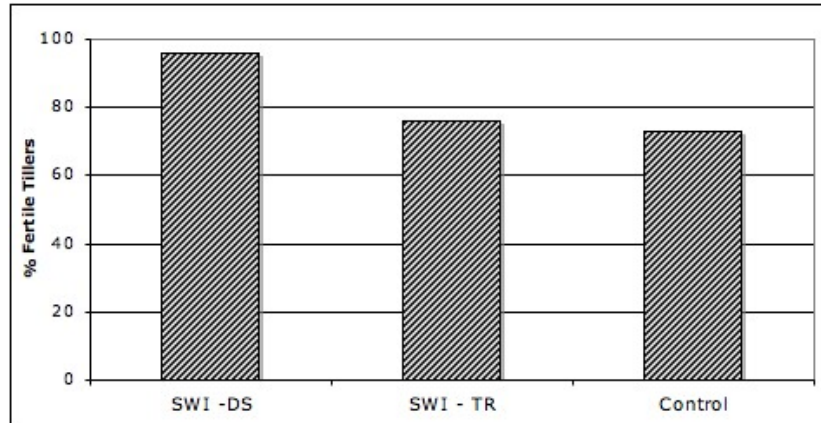


Figure 2: % Fertile tillers for the SWI DS, SWI TR and the control

Number of plants/m<sup>2</sup> and number of panicles/m<sup>2</sup>: A stark contrast between the SWI and the traditional system occurs with the number of plants /m<sup>2</sup>. This was for SWI SD 12.4 and for SWI TR 14.5, down from 16 plants/m<sup>2</sup> seeded and transplanted, compared to 92 plants/m<sup>2</sup> in the control. Calculating the number of panicles/m<sup>2</sup>, the control treatment had the highest number with 248, followed by SWI SD with 219 and SWI TR with 144.

Panicle length and number of grains/panicle: Panicle length between the two systems was strikingly different. Panicle length was more than double for SWI compared to control, or 10.2 cm for SWI SD, 8.4 cm for SWI TR, and 4.2 cm for the control. The number of grains/panicle was also highest for SWI SD with 58, followed by SWI TR with 42, and the control with 35.



SWI panicles (left) and control panicles (right), the differences are so large that it is hard to believe that these panicles come from the same seed!

Average length SWI direct-seeded panicle was 10.2 cm; for the control it was 4.2 cm long

Thousand-grain-weight: this statistic was highest with SWI DS being 28.1 g, a little lower with SWI TR with 27.0 g, and remarkably lower for the control with 21.1 g.

### 3.2. Weeding

Weeding practices were applied for the SWI treatments as done under SRI. The cono-weeder was used after plants were well-established, on average 2 times in SWI DS, and 1-2 times in SWI TR. Hand weeding complemented cono-weeding by removing weeds that were close to the plant base. For the control, all weeding was done by hand. Times needed for weeding are shown in the following table.

Table 4: Weeding time in SWI and control plots, and number of weedings during the cropping season (average of three villages)

	<b>SWI - DS</b>	<b>SWI -TR</b>	<b>Control</b>
Hand weeding	1-2 times	0-2 times	1-2 times
hours/ha	86	68	294
Cono weeder	2 times	1-2 times	-
hours/ha	63	34	-
Total weeding hours/ha	149	102	294
Total weeding (person day/ha)	18.6	12.8	36.8

Total weeding time in the control plot (36.8 person days) was two and three times higher compared to the SWI DS (18.6 person day) and SWI TR (12.8 person day), respectively. In SWI TR, less time was needed compared to SWI DS. Transplanted seedlings were bigger than weeds, thus there was less competition between wheat and weeds, and the weeding was less labor-intensive. In the direct-seeded treatment, on the other hand, both weeds and wheat germinated at the same time, and controlling weeds needed more time.

Comparing weeding time for wheat and rice, hand weeding the control plots with wheat required 37-person days/ha, whereas for rice, it was 28-person days/ha (Styger, 2009). With a broadcast crop such as wheat, it is difficult to distinguish between the crop and the weeds, and removing weeds takes longer compared to rice, which is transplanted into pockets.

### 3.3. Irrigation

For the SWI plots, we followed the same irrigation principles as with last season's SRI plots: to apply just the amount necessary to maintain an estimated optimum level of moisture in the soil. Unlike rice, wheat does not tolerate flooding, and more than 48 hours of stagnant water damages the crop. Thus, conventional irrigation management for wheat already alternates irrigating and drying of the plot, similar to SRI irrigation principles. Following their conventional practice, farmers irrigated their plots to a depth of 5cm. Due to the light texture of the soils, this irrigation water infiltrated after one day. We monitored the number of irrigations and the time required to irrigate the different



treatments (see Table 5).

Table 5: Time and number of irrigation for two SWI treatments and the control

	<b>SWI - DS</b>	<b>SWI -TR</b>	<b>Control</b>
Number of irrigations	9	8	9
Time of irrigation (hours/ha)	298	285	405
Time of irrigation (person day/ha)	37	36	51
Irrigation time (% of control)	74%	70%	100%

The number of irrigations was the same for both SWI and the control, except for one irrigation less for the transplanted version, because transplanting took place after the first irrigation had taken place in the other treatments.

To our surprise, irrigation water use was reduced by 26% for SWI SD and by 30% for SWI TR compared to the control. There are two major reasons: i) water is distributed more quickly and evenly across well-leveled fields; thus less water was needed compared to non-leveled plots, and ii) organic matter application had a remarkable impact on the water-retention property of the soils. Organic matter reacted like a sponge and retained water longer in the crop-rooting zone. Thus it was possible to use less water for each irrigation event. Control plots, on the other hand, with low soil organic matter content, had a lower water-holding capacity. Irrigation water infiltrated quickly to greater soil depths and was no longer available to the plants.

### 3.4. Some considerations on labor

Labor requirements for the three treatments are shown in Table 6.

Table 6: Labor required for various cropping activities for two SWI treatments and the conventional system (person day/ha)

	<b>SWI - DS</b> person-days/ha	<b>SWI -TR</b> person-days/ha	<b>Control</b> person-days/ha
Soil preparation	28	28	26
Seed coverage	-	-	88
Seeding	32	1	3
Nursery management	-	10	-
Transplanting	-	20	-
Weeding	19	13	37
Irrigation	37	36	51
Harvest* (estimated from rice)*	31	31	31
Threshing (estimated from rice)	14	9	13
<b>Total labor</b>	<b>160</b>	<b>147</b>	<b>248</b>
Yield (kg/ha)	2220	1400	1970
Wheat grain yield /day of labor (kg)	13.8	9.5	7.9

\* SRI report (Styger, 2009, p.29)

\*\* SRI report (Styger, 2009, p.29), to thresh 1 ton of rice took 6.2 person day

Labor needed for soil preparation under SWI was slightly greater (28 person-days) compared to control (26 person-days) due to the necessity of field leveling. Nevertheless, the time needed to level the small plots was minimal.

The most labor-demanding task for the wheat crop was the time needed to cover seeds with soil: 88 person-days/ha. This includes digging the soil, its transportation to the wheat field, and covering the seeds. In the control plots, farmers covered seeds with soil four times over a period of 15-20 days after seeding.

To plant the crop, both SWI treatments - the direct seeding in pockets by hand, and the transplanting of seedlings - required about 31-32 person- days/ha. On the other hand, broadcasting of seeds - as done in the control plots - required only 3-person days/ha.

As seen above, labor for weeding and also for irrigation was significantly lower in the SWI treatments compared to the control plot. We estimate that harvest time is the same in the three treatments, and that threshing time is proportional to yield.

In total, labor requirement under the SWI system was only 60-65% (or between 147-160 person day/ha) of that needed for the control plots (248 person day/ha). Looking at the returns per day of labor, the farmers produced under SWI DS 13.8 kg of wheat, under SWI TR 9.5 kg, and under the control treatment 7.9 kg, which is an increase from SWI SD to the control of 74%. Thus, despite the fact that the yields were not very satisfactory this season, the saving of labor alone should make SWI an attractive alternative to farmers.

## **4. Discussion**

### **4.1. Low yield levels**

An important reason for low yield levels was the planting of the crop in late December/early January. Under an optimal cropping calendar for wheat in this area, planting is done between October 15 and November 15, and harvesting no later than the end of February. This way, the crop can develop during the cool season, from November to February. By March, temperatures are rising again, and hot winds are blowing. In our test, flowering and grain-filling, a critical stage for yield determination, took place in March. According to Bitzer and Herbek (2009), the longer this filling period lasts, the greater the chance for a high yield. If this period is shortened due to hot, dry weather or serious disease conditions, yields will tend to be lower.

A reason for late planting is the difficulty for farmers to prepare, plant and irrigate the wheat fields while the rice crop is still growing. Wheat and rice are not planted on the same fields. Wheat prefers a light soil, and rice is planted on heavy clayey soils. As most diesel motor pumps are used during the main season in the rice fields, and during the off-season moved to the wheat fields, availability of the diesel motor pump may be another reason why fields are planted late. Nevertheless, farmers adopting SRI practices during

the main season can shorten the rice cropping cycle by one to two weeks, as witnessed during the SRI evaluation in 2008/2009 (Styger, 2009). This would allow planting the wheat crop one to two weeks earlier, which can make a significant difference in targeting the optimal cropping calendar. Another reason that further delays the cropping season is the practice of covering seeds with topsoil. A good diagnostic at the village level would be important, to identify ways how to respect the optimal planting times.

#### **4.2. Plant spacing under SWI was too wide**

Spacing at 25cm x 25cm, as for SRI, was apparently too wide. Wheat plants did not establish good ground coverage, and there was much empty space between plants, despite the high number of tillers/plant under SWI. A denser planting can be recommended. Optimal density is yet unknown. It should be wide enough that wheat plants can tiller profusely, but dense enough that empty spaces between the plants can be minimized. With an increased number of plants/m<sup>2</sup> and the high tillering rate of SWI plants, we may expect yield levels to increase significantly beyond this first year's results.

#### **4.3. Pocket mortality under SWI was too high**

Another yield- reducing factor was the mortality of the SWI pockets. The mortality rate was higher under the direct seeded treatment (22%) compared to transplanted (9%), and higher when direct-seeded into dry soil (28%) as compared to humid soil (11%).

Seeding one seed per pocket did not allow for a buffer in case of germination or early transplanting problems. Thus, it might be better to seed 2-3 seeds/pocket, which can be thinned to 1 plant/pocket once the plants are established. Various seeding techniques should carefully be evaluated, including thinning tried out several ways. Next to plant establishment and growth observation, labor requirements should be carefully monitored, in order to assess the optimal returns to the management of this cropping phase.

Direct seeding onto moist soil is an innovation for the region, as farmers normally broadcast their wheat seeds onto dry soil. As tested in one village, the survival rate, plant establishment and subsequent growth of wheat plants were much improved in the plot that was irrigated before seeding. Farmers traditionally adhere to dry seeding to avoid germination before the seeds are covered with soil.

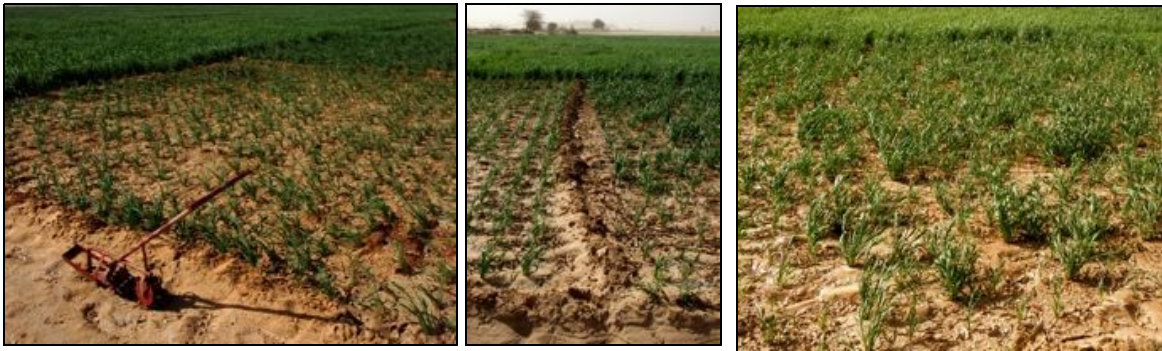
#### **4.4. Direct seeded SWI performed remarkably better than transplanted SWI**

It was an absolute novelty in the region to transplant wheat seedling from a nursery. Wheat seedlings at the two-leaf stage were far more fragile, and their stems were much weaker than for the rice seedlings at the same level of development.

Transplanting did not improve but rather slowed crop development as compared to direct seeding. Recovery after transplanting shock took some time, whereas the direct-seeded plants grew faster and more vigorously. In all three villages, all measured yield parameters – such as the number of tillers/plant, panicles/plant, panicles/m<sup>2</sup>, % fertile

tillers, panicle length, and number of grains per panicle-- were substantially lower under SWI TR compared to SWI SD. The only superior result was the improved survival rate of 91% for SWI TR compared to 78% under SWI SD. Crop development and subsequent ripening of the panicles under SWI TR were not as uniform as under the direct seeded treatment, and some of the smaller and younger panicles were not fully ripe at harvest.

It would seem that transplanting from a nursery is not a viable alternative for wheat, although this result should probably be evaluated in another trial now that farmers are gaining experience with both SRI and SWI concepts and practices. Future efforts should focus on further developing the direct-seeding technique in pockets.



SWI transplanted - SWI direct seeded

SWI treatments in Horogougou: Note a better survival rate of SWI TR compared to SWI SD, but its plants have fewer tillers compared to the direct-seeded plot.

#### 4.5. Observations on tillering and the crop cycle

Highest increase in tillering was observed in SWI immediately before flowering. This differs from our observation of the SRI crop, where the increase of tiller numbers declined before flowering (see graphs). In the control plots, tiller increase after 40 days seemed linear.

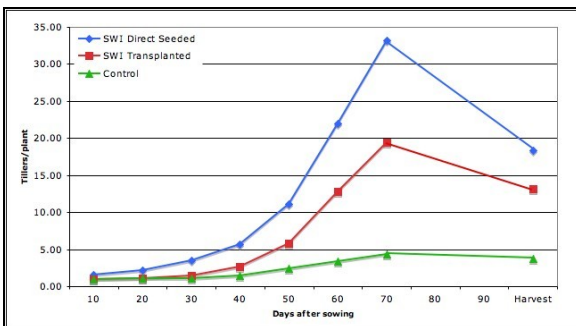


Figure 3: Tiller development under SWI – note the initial slow increase, until 40-50 days, when tiller numbers increased much faster until flowering at 70 days.

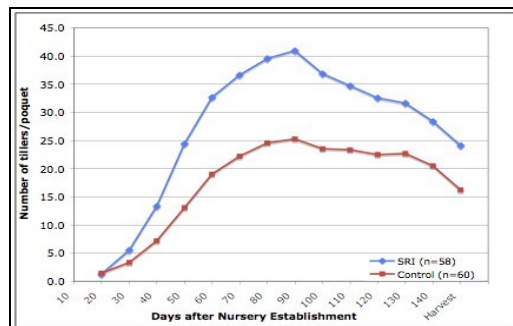


Figure 4: Tiller development under SRI – note the fast increase in the beginning, before it slows down as flowering approaches at 90 days (graph from Styger, 2009a, page 23)

For the SWI plants, the growth period seemed to extend longer, and SWI plots remained green longer compared to the traditional plots, although harvest could be done at the same time. Crowding of plants in the control plots seemed to accelerate both yellowing of the plants and their maturation, thus reducing the length of the grain-filling period. This certainly resulted in the lower 1,000-grain weight in the control (21.1 g) compared to the SWI treatments (27g and 28.1 g). Interestingly, this observation is contrary to what we observed with the SRI rice crop, which developed faster than the control plots. The crop cycle under SRI was one to two weeks shorter compared to the control plots (Styger, 2009a).



SWI plot in Hara Hara at 83 days after seeding. SWI plot in front, control plot in the back. SWI fields stayed longer green and had a longer grain filling period compared to the control plots.



SWI test in Douegoussou 75 days after seeding. SWI plot in front, control plot in the back. SWI plots had a prolonged grain-filling period. In the control, where plants were crowded, maturation was advanced. Plots were harvested at the same time.

#### 4.6. The practice of covering seeds with external soil

The practice of covering seeds with external soil shows a number of disadvantages: i) extremely high labor requirements, ii) delay in establishing the crop, and iii) environmental degradation around the wheat fields from removal of topsoil and digging around tree roots,

The second and third points were discussed earlier. The first point can be illustrated by what happened this year in the village of Horogoungou. It took villagers three weeks to dig, transport and apply soil to a 3.5 ha PIV. Although the PIV had already been seeded (into dry soil) in early December, the first irrigation could only be done by late December, after the soil covering was finished. This pushed the cropping period back into the non-optimal period for wheat cultivation, so that the maturing phase coincided with increasing temperatures and the hot winds. Thus, this delay had a yield-reducing impact.

## 5. Conclusions and recommendations

Yield levels for our tests were low to medium compared to the regional average. We attribute this to a late planting under which wheat maturation coincides with the hot winds and rising temperatures, thus reducing yields. Direct-seeded SWI showed a 13% yield increase over the control, but yields under the transplanted treatment were 29% less than the control. While a 13% increase is not very high, we believe that there is much potential for further yield increase by reducing plant spacing, reducing plant mortality of pockets, and by working out more optimal timing for planting. Optimal plant spacing is still to be determined; future tests could try spacing plants within the line at 20cm, 15cm and 10cm. Spacing of 25 cm between the lines could be maintained, or slightly reduced to 20 cm, to allow the use of the cono-weeder. With the reduction of plant spacing, the number of plants/m<sup>2</sup> will increase. In combination with the observed higher tillering rate, the high percentage of fertile tillers, the larger panicles with a larger number of grains, and a higher 1000-grain weight, there could be much potential for significant yield increases compared to what we obtained this year.

Significant improvement with SWI was obtained in labor and water productivity. Labor requirement for SWI was reduced by 35-40% compared to the control. The return to labor (wheat produced per unit of labor) under SWI SD increased by 74% over the control. Alone these findings should make SWI attractive to farmers. SWI allows also starting the cropping season earlier, as no time is needed for seed covering, which by itself will already improve yield levels.

The practice of covering seeds with external soil results in the disadvantages of environmental degradation, extremely high labor demand, and a delay in the start of the cropping period. This old practice could be replaced by the application of organic matter, such as manure or compost. Manure and compost would improve soil structure, provide improved fertilization over topsoil application, and would improve the water holding capacity of these light soils. Manure application together with a good field leveling has led to a saving of irrigation water needed of 25-30%, an important consideration in the region, where water limitations present a major constraint. Organic matter acted like a sponge, and soils remained moist with less water

Transplanted wheat, a great novelty in the region and in Mali, seems less promising. Seedlings at the two-leaf stage were more fragile than rice seedlings at the same stage. Transplanted seedlings did not grow quickly and vigorously, and showed a delay in development compared to the direct-seeded treatment. All yield parameters were lower compared to the direct-seeded treatment. Given that these results are based on only one trial, however, it would be good to retest, by also taking into account proposed modifications from this first SWI experience.

Focus on developing direct-seeding techniques points to testing seeding machines, where seeds are covered at the same time as the seeding is done. Seeding machines for small-seed crops, such as wheat and rice currently available in Mali, allow only for seeding in continued lines. We plan to have a prototype of a simple seeding machine developed that

can seed wheat in pockets. With efficient seeding techniques, it would become much easier to target the optimal cropping calendar for wheat. This might by itself improve wheat yields. With pre-irrigated soils and the use of soaked seeds, germination of wheat will be faster and more uniform compared to current practices. Seeding 2-3 grains/pocket, to be thinned to 1 plant/pocket, will allow for a high--ideally 100%-- survival rate for plants in the pockets.

## 6. The SWI Farmers



Chef de Village Amirou from Horogoungou village, and Harouna Ibrahim – Africare technician and co-author of this report



Harouna and SWI farmer Mahamane Houssa, from the village of Hara Hara, in his SWI plot



SWI farmer Mahamane Abdoulaye (on the right) from the village of Douegoussou, in his SWI plot.

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