Title: System of Wheat Intensification (SWI): A new concept on low input technology for increasing wheat yield in marginal land.

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System of wheat intensification (SWI): A new concept on low input technology for increasing wheat yield in marginal land.

Abstract: *During the wheat growing season of 2010, farmers' field trials were carried out in four districts of Far Western Nepal to demonstrate the System of Wheat Intensification (SWI). The trials were carried out by two different organizations; Mercy Corps Nepal and FAYA Nepal while implementing food security projects in these four districts; Dadeldhura, Doti, Baitadi and Kailali. The overall objective of the trial was to test the technology in farmers' field and compare the yield from SWI with yield from traditional practice. For this purpose, the participating farmers were organized into groups, trained on SWI technology and field trails were conducted under the close supervision of project team. Mercy Corps Nepal adopted its Participatory Action Research (PAR) framework and "Farming as A Business" (FAAB) intervention modality for commercial orientation while FAYA Nepal conducted demonstration trainings for testing this technology. The results indicated that the average grain yield increased by 91 to 100 percent with adoption of SWI technology compared to traditional practice. Farmers responded positively to the results of the demonstration and those who participated in the PAR and demonstration trainings were willing to adopt SWI, given that the yield is increased significantly to meet their household level food security. Since seed priming, line sowing, gap filling and weeding are some tedious tasks required to perform in SWI, introduction and use of simple tools for seed sowing and weeding is recommended for ensuring wider adoption of SWI in this region. Results have shown that increased yield through complete SWI technique can ensure food availability for extra 6 months for a typical 6-member household with average land holdings. So, SWI technique is very crucial for the food security of poor, marginal and landless farmers of Far Western Region where wheat is a major food item.*

Key words: Food Security, System of Wheat Intensification, Action Research, Demonstration Training

INTRODUCTION

Wheat (*Triticum aestivum* L.) is world's most widely cultivated food crop. It can be grown from below sea level to 5000 m altitude and in areas where rainfall ranges between 300-1130 mm. Wheat contributes more calories (20%) and more protein to the world's diet than any other food crop. Before 1960s only traditional varieties of wheat were cultivated. Those varieties were tall, suited to low management with low yield potential. The turning point in the history of the wheat came after 1963 with the introduction of dwarf, photo-insensitive, high yielding Mexican wheat breeding materials (Norin Gene) developed by Dr. Norman E. Borlaug. Traits such as increased number of fertile florets, length and density of spike, reduction of shattering, disease resistance and greater responsiveness to fertilizer without lodging were also found in these Mexican varieties. Introduction of semi dwarf varieties increased the consumption of fertilizer per unit area tremendously and promoted mechanization in agriculture. In one side it increased the over all production and postponed the near seen dangerous cloud of the great famine due to population explosion in the third world where there was very low growth rate of crop production as compared to population growth. However in long term advantages of green revolution were taken only by developed country and farmers who were fortified by irrigation, mechanization and high agro inputs. But at initial decades of 21st century another probability of great famine appeared in the world due to long drought in tropical and subtropical and at the same time it appeared more dangerously because most of the developed countries adopted policies of using consumable grains into biofuel production. Therefore another very serious initiative was needed to increase the productivity of major crop in the very marginal land with low input and sustainable way. In this context, in many parts of the third world System of Rice Intensification created government attention. This technology has high potentiality to provide high yield per drop of water and per kg of agricultural inputs like fertilizer, seed etc. Some community workers in India and Africa use the same principle of rice cultivation in wheat crop, which gave very enthusiastic results. This technique of wheat cultivation is now known as System of Wheat Intensification (SWI).

Wheat is the third major important cereal grain after rice and maize in Nepal. It occupies 20.33% of total cereal area and contributes 16.56% of the total cereal production in the country. The area, production and productivity of wheat in Nepal in fiscal year 2005/06 was 672040 ha, 1394126 tons and 2.07MT/ha, respectively. The average productivity of wheat in Nepal is very low (2.07 MT/ha) as compared to developed country (6-7 Mt/ha). The low productivity of wheat in Nepal is mainly due to three reasons; low use of production inputs like seeds, fertilizer etc, lack of irrigation and poor soil fertility management practices. Lack of suitable high yielding varieties, slower seed replacement rate, sterility and incidence of diseases are some other factors which are restraining the wheat yield in different agro-ecological zones. In hilly areas, transportation of seeds and fertilizers is very difficult due to undulating topography and poor access. In this condition, better management of soil with low seed rate is the best option for reducing the cost of production for wheat. SWI is a technology of wheat production which is based on manipulation of soil environment with minimum external input and very low seed rate. Therefore the problem of low productivity of wheat in hilly region of Nepal could be addresses by SWI techniques but some more work should be done to make this technology more suitable in local socio economic and ecological conditions.

System of Wheat Intensification (SWI) which is based on the principles of System of Rice Intensification (SRI) is a new wheat cultivation technique which demands to maintain plant to plant distance at 8 cm and 20 cm between lines. This kind of sowing with proper plant density allows for sufficient aeration, moisture, sunlight and nutrient availability leading to proper root system development from the early stage of crop growth. After sowing, it is necessary to maintain plant population by gap filling and thinning of crowded seedlings. Besides this, 2-3 times weeding and irrigation is required for best results. These practices are carried in the early stage of wheat growth as associated with the principle of intensive care. System of Wheat Intensification (SWI) is one of the promising technologies to increase productivity which ultimately contributes to the household level food security of marginal farmers.

SWI has been successfully promoted by many agencies like PRADHAN (2007), an NGO in Bihar with World Bank funded project and Agriculture Technology Management Agency (ATMA) of Government of India, People's Science Institute (PSI) another NGO in Uttarakhand (2008) in India and USAID in Mali (2009). SWI has been tested as innovative approach to increase productivity and being practiced in India, China, Ethiopia, Poland and USA. SRI has already been tested and evaluated by several NGOs, Nepal Agricultural Research Council (NARC) and the Department of Agriculture, but SWI is still a new technology for wheat cultivation in Nepal. SWI is evolving and being tested in many places. Mercy Corps has attempted to test the validity of this technology by conducting Participatory Action Research in 2010. Similar experiments were also conducted by FAYA Nepal in Kailali district to demonstrate this technology. The main objective of this trial is to compare the yield from traditional practice with that from

SWI. Results has shown that grain yield of wheat is increased by 91% at its maximum, with adoption of this technology. Similar results were obtained from the demonstration trials under Farmers Field School conducted by FAYA Nepal in Kailali district.

Principles of the System of Wheat Intensification (SWI)
The prevalent system of wheat cultivation requires more chemical fertilizers and nearly 120-180 kg of seed per hectare. SWI uses only 20-30 kg of improved seed in one hectare. Twenty to twenty five cm spacing between rows, use of manure and organic seed treatment ensures higher yield. Sufficient spacing between the plants and sowing of two seed grains at one point facilitates desired moisture, aeration, nutrition and light to the crop roots. This helps faster growth of plants. Only 2-3 times irrigation and weeding through cono-weeder save time and expenses on labor.
SWI is primarily based on these two principles of crop production

1. Principle of root development and
2. Principle of intensive care

Principle of root development:
For the proper development of crop plant, it must be well established from rooting system. Root development is the first step of healthy growth and development of any plant. For this, it requires proper nourishment and sufficient space around the plant. So, distance between plants is very crucial for proper growth and development of crop plants.

Principle of intensive care:
Intensification does not mean high number of plant density per unit space; rather it is proper space maintenance and taking care of plants very closely. So, to enhance productivity it requires intensive care in every stage of plant growth specially management of weed, insect, disease, organic manure and irrigation.

Based on the above principles the System of Wheat Intensification involves the following modified practices for achieving higher productivity

Improved Seed: SWI can be applied for any kind of wheat variety, however the local varieties used under current practice in the hilly districts of Nepal are less productive compared to newly release improved varieties like WK 1204 and Pasang Lhamu. So, selection of improved varieties will be crucial in increasing the productivity of wheat crop.

Seed Treatment: Seeds are usually treated with Bavistin or Vitavax to control seed borne fungal diseases including smut. In addition to this, seeds are treated with organic mixture of well decomposed compost, jaggery and cow urine for improving microbial activity in the soil.

Procedure for Seed Treatment:

- Grade out bold seeds separately from lots of improved seed.
- Take 10 liter of hot water (60 degree Celsius) in an earthen pot.
- Dip 5 Kg of improved graded seeds in it.
- Remove the seeds which float on the top of water.
- Mix 2 kg well decomposed compost, 3 liter cow urine and 2 kg of jaggery.
- After mixing it properly, keep the mixed material as such for 6-8 hour.
- After this, filter it so that solid materials along with seeds and liquids get separated.
- After that, mix 10 gm of fungicide properly and keep in shade for 10-12 hrs.
- Then wheat gets germinated. The germinated seed is used for sowing in the tilled field.
- Cow urine, well decomposed compost and jaggery in separate vessels

Land Preparation and application of Organic Manure: Traditionally, farmers accumulate organic manure in open field for months, before final land preparation which results in the loss of nutrients through leaching and evaporation. SWI emphasizes on efficient use of organic manure rather than chemical fertilizers because it helps to improve the soil health in addition to providing nutrients to the crop. Organic manure is applied before land preparation at the rate of 10 quintals per ropani and incorporated in the soil by plowing immediately.

Seed Rate: In traditional method, 8-10 kg of wheat seed is required for 1 ropani but seed rate is lowered to 1-2 kg per ropani under SWI. Treated seeds have high germination rate. So, sowing treated seeds in lines 20-25 cm apart saves a large amount of seed and reduces the cost incurred in it.

Line Sowing: Maintaining plant to plant distance is very important for facilitating proper root development and tillering in wheat crop. So, two seeds are sown per hill and spacing is maintained at 20 cm x 20 cm. Seeds are sown at a depth of 2.5 – 3 cm using seed drill. If seed drill is not available, strings or ropes are used for maintaining proper spacing. Moisture should be available in the field while sowing germinated seed.

Gap Filling: Wherever the seeds have not germinated, the gap should be filled with germinated seeds within 10 days of sowing. If there are more than two seeds germinated in one hill they should be uprooted properly to facilitate proper growth of the plant.

Irrigation: First irrigation is done 15 days after sowing, as root initiation starts during this time. Unavailability of moisture in soil prevents root initiation. Second irrigation is given 25 days after sowing, as tillers start emerging in this stage. Third irrigation is given 35- 40 days after sowing. Subsequent irrigations are given at 60, 80 and 100 DAS upon availability. During the flowering and grain-filling stage, appropriate moisture should be available in the soil.

Weeding: After the first, second & third irrigations, hoeing and weeding should be done using cono-weeder[1] to loosen the soil and to make the wheat field free from weed. The loosening of soil results in better aeration for the root zone and increases the root length by letting them take more moisture & nutrient from the soil. This helps in bringing forth more tillers in the plant with more vigor.

Crop Rotation with legumes for increased productivity:
In hilly area wheat is mostly cultivated in rotation with upland rice and millet, year after year. Growing same crops in the same field for many years depletes the soil fertility and helps to build pests and pathogens in the cropland. So, rotating legumes like soybean and pulses will help to improve productivity of wheat by adding nutrient to the soil and improving soil properties. Wheat crop yields more in rotation with legumes because legumes help to fix nitrogen in soil and improve soil fertility. Legumes like soybean have bacteria in their root nodules which take nitrogen from the air and convert them to usable forms.

In comparison to wheat-rice/millet rotation wheat-maize/soybean will be more beneficial cropping pattern in a long term because in addition to improving soil fertility, crop rotation with legumes will also help to check the build-up of pathogens and pests in the cropland and reduce the expenditure on agricultural chemicals. Green Manuring with Dhaincha can also improve the soil fertility status.

Management of Organic manure/FYM:
Hilly people rely completely on Farm Yard Manure (FYM) for fertilizing their field. It is for thisreason that every household in far western hills rears cattle for income generation. Application of chemical fertilizers increases the yield for a certain period, but at the same time it also spoils the soil by destroying the soil properties. On the other hand, organic manures release nutrients slowly, in small proportion but

steadily. So, nutrients are available for a longer period of time. FYM also helps to increase the microbial activity in soil and improve soil properties.

Organic manures are best suited for the hilly regions as it is locally available and easy to prepare. However, the current management practices need some improvement for better results. Traditionally, farmers accumulate FYM in the field for a long time before final land preparation, subjecting the FYM to nutrient loss through leaching and volatilization. Similarly, farmers do not collect cattle urine for making FYM, although it is a rich source of nitrogen for soil. The following points should be considered for proper compost making:

- FYM should be protected from rainwater because it leaches the nutrients
- FYM should be protected from sunlight to prevent volatilization of ammonia
- Cattle urine should be collected and utilized properly
- Only well prepared FYM should be used in the field
- FYM should be incorporated in the soil properly

cono-weeder[1] is a manually operated machine used for weeding between rows of paddy or wheat crop. It has two conical rotors mounted in tandem with opposite orientation. Smooth and serrated blades mounted alternately on the rotor uproot and bury weeds because the rotors create a back and forth movement in the top 3 cm of soil, the cono weeder can satisfactorily weed in a single forward pass without a push or pull movement.

MATERIALS AND METHODS

Participatory Action Research (PAR) by Mercy Corps

PAR was carried out by Mercy Corps Nepal in collaboration with District Agriculture Development Offices (DADO) in 16 sites of three working districts – 4 sites in Dadeldhura, 8 sites in Baitadi and 4 sites in Doti). The high yielding wheat variety WK-1204 was selected for test with three treatments and local practice as check. Seed priming was done soaking in lukewarm water overnight followed by mixing with cow urine, jaggery and well decomposed compost. Then the seeds were left to dry under shade for 4 hours. The treatments were T1 (seed priming + line sowing), T2 (seed priming + broadcast method), T3 as (without priming + local practice of sowing) and T4 control (local variety + local practices). An area of 150 m^2 was allocated for each trial providing 50 m^2 for each plot/treatment. The manure was applied @15 MT/Hacter to all treatments, while seed rate was maintained @30 Kg/Hacter for T1, 80 Kg/Hacter for T2 and T3, and 120 Kg/ha for T4.

Most of the trial sites are of sandy loam soil with rice as previous crop. Weeding and irrigation was carried out 3 times in each plot. Data on various plant growth and yield parameters were recorded. Crops were harvested and yield of each plot were compared in active participation of involved farmers and technicians from the project.

Table 1: PAR sites and land types

Baitadi		
	1. Dilasaini(1)	Lowland
	2. Ganjari (Baitadi)	Upland
	3. Sigash	Lowland
	4. Dilasaini(2)	Upland
Dadeldhura		
	5. Kaipalmandu	Lowland
	6. Manilek	Upland
	7. Koteli	Lowland
	8. Alital	Lowland
Doti		

9. Barpata	Lowland
10. Kalena	Upland
11. Khatiwada	Lowland
12. Kalikasthan	Upland
13. Ganjari (Doti)	Upland
14. Gairagaon	Lowland
15. Baglek	Upland
16. Daud	Upland

Treatments

T1 – Seed priming + Line Sowing
T2 – Seed Priming + Broadcasting
T3 – No Seed Priming + Broadcasting
T4 – Control (Local Seed + Local Practice)

Plant Growth Parameters

Plant height in centimeter (cm)
Number of tillers per plant
Length of spike in centimeter (cm)

Crop Yield Parameters

Maturity days
Number of grain per spike
1000 grain weight in gram (gm)
Grain Yield Kilogram (Kg) per ha

SWI Demonstration - Experience from FAYA Nepal, Kailali

In 2010/11 FAYA Nepal introduced SWI techniques in Kailali under European Union Food facility project. Four demonstrations were established in three VDCs namely Ramsikharjhala, Lalbojhi and Fulbari. Twenty five farmers were selected to participate in demonstration training in each VDC. 300 m^2 were allocated for demonstrating SWI and 300m^2 for farmer's method in each site. Field was pulverized by two to three ploughings, planking and racking. Seed were selected by mild hot water for 10 minutes. All floated seed were removed and sedimented one were used only for sowing. Then seed were treated with mixture of jaggery, cow urine, water and vermicompost. Seed were allowed to germinate for 12 hours. After germination seed were sown at a depth of 3-4 cm and distance of 20 cm plant to plant and 20cm row to row. Two germinated seed were placed at one location by hand dibbling.

During land preparation well decomposed FYM was incorporated at the rate of 10 MT per ha. After 10 days of sowing gap filling was done by dibbling the seed. Twenty days after sowing (DAS) light irrigation were provided. 25 DAS weeding were done with the help of cono weeder. Similarly second irrigation and weeding were done at 40 DAS and 45 DAS, third irrigation and weeding at 60DAS and 65DAS. Harvesting was done after complete ripening of crops. Each five plants were selected for taking data. Phenological data like plant height, leaf length, leaf breadth, number of tillers were taken for SWI as well as farmers' methods. Similarly harvesting parameter like spike length, number of spike per hill, number of grains per spike, thousand grain weight and number of spike per m^2 were recorded. Cost of cultivation and price of production were also taken to assess the financial viability of the technology.

RESULT AND DISCUSSION

Plant height is more or less equal in all cases of treatment, but the number of tillers differs significantly and so does the length of the spikes in case of T1 and T4.

Table 2: Plant Growth Result

SN	Treatments	Plant Height (Cm)	# of tillers per plant	Length of Spike (Cm)
1	T1	88.5	14.35	9.21
2	T2	88.1	11.25	8.91
3	T3	79.8	3.05	6.90
4	T4	89.2	2.01	5.80

With the increased numbers of tillers and spike lengths, there is a yield difference of nearly 100% increased between T1 and T4.

Table 3: Crop Yield Result

SN	Treatments	Maturity days	# of grains/spike	1000 grain weight (gm)	Grain yield kg ha^{-1}
1	T1	157	74.95	62	6516
2	T2	153	69.6	58	4524.7
3	T3	145	53.2	52	3738
4	T4	135	44.3	48	3405.5

There is almost double yield increased in case of SWI treatment as compared to local practice.

Table 4: Yield based on Land Types

Land Type	Treatments	Yield
Lowland	T1	6472.75
	T2	4523.00
	T3	3796.75
	T4	3364.00
Upland	T1	6559.25
	T2	4526.37
	T3	3679.25
	T4	3447.00

Number of grains per spike was significantly higher i.e.75 per spike in T1 compared to 44 per spike in T4. 'Days to maturity' was higher in primed plot compared to non-primed plot and highest with line sowing. In this study the wheat seeds were sown early in the month of November, so higher spring temperatures did not affect the grain yield.

1000 gm weight of wheat grains was highest for T1 and lowest for T4. Maturity was delayed in primed plots resulting in a higher grain filling period which in turn resulted in heavier grains compared to non-primed plots.

Seed priming had significant effect on tillering however variety did not significantly affect tillering. Wheat grown on primed plots had more tillers than in non-primed plots. The highest number of tillers obtained with line sowing can be explained by the fact that tillering is reduced with higher plant population due to reduced photo-active radiation at the base of the crop canopy. Priming and line sowing also seemed to have positive impact in the plant growth. The higher yields from primed plots can be attributed to the longer plants and spikes as a result of seed priming.

Table 5: Enterprise Budget (Local)

Items	Local			
	Unit	Qty	Unit Price	Total Cost
INPUTS				
-Labor	Days	3	400	1200
-Draft	Days	2.6	500	1300
-Materials	Kg			
a) seed		8	40	320
b) FYM		700	0.5	350
Total Cost				3170
OUTPUTS				
Grain Yield	Kg	170	40	6800
Straw	Kg	600	2	1200
TOTAL RETURN				8000
NET PROFIT				4830

Local practices of wheat cultivation are very simple which has very nominal cost and very low productivity. One of the main reasons is traditional wheat variety in use with low productivity. But the local farmers are evaluating variety in terms of taste, local adaptability, straw yield and resistant to different diseases. They consider their local variety more hardy and easy to handle.

Table 6: Enterprise Budget (SWI)

Items	Local			
	Unit	Qty	Unit Price	Total Cost
INPUTS				

-Labor -Draft -Materials a) seed b) FYM c) Jaggery d) Plant Protection	Days Days Kg Kg Kg	7 3 2 1000 1 0.01	400 500 50 0.5 100 1000	2800 1500 100 500 100 10
Total Cost				5,010
OUTPUTS				
Grain Yield Straw	Kg Kg	326 900	40 2	13,040 1,800
TOTAL RETURN				14,840
NET PROFIT				9,830

With the adoption of SWI technology, farmer can increase the yield by more than 156 Kg per Ropani of land. In Far West, average land holding is more than 5 ropani, so if farmer adopts SWI in around 5 ropani of land, there will be increment of wheat more than 780 Kg, which will be food sufficient to 6-member household @ 4 Kg/day wheat for more than 6 months as per Rural Community Infrastructure Works/Food for Work, Government of Nepal, 2010 standard.

Table 7: Phenological and harvesting character s of wheat plant grown in SWI and normal planting indifferent VDCS of Kailali in 2011.

SN	Parameters (Average of 10 plant)	Fulbari		Lalbojhi		Ramsikharjhala	
		Farmer's practice	SWI	Farmer's practice	SWI	Farmer's practice	SWI
1	Tiller number	5	25 (18-36)	4	34 (22-54)	3	25 (19-42)
2	Number of spike per hill	5	22.5	4	33	2.4	23.5
3	Number of grains per spike	22.5	45.4	50.1	72.4	60	80
4	Number of spike per sq m	310	400	414	446	210	256

5	Spike length (cm)	9	16	9.3	12.3	13	18
6	TGW (gm)	50	75	40	45	45	50
7	Productivity (Mt/ha)	4	8	5.8	7.95	4.8	6.95
8	Different in productivity	100		37		44	

In the demonstration the productivity of wheat was recorded up to 8 MT/ha which is almost two times than the normal planting in same field and approximately four times than national average with 1/10 times lees seed. All parameter including leaf length, leaf breadth, spike length, number of grains per spike, TGW, number of spike per hill and number of spike per 1 m^2 was comparatively higher in SWI techniques than normal planting.

CONCLUSION AND RECOMMENDATIONS

The study shows that wheat crop responds positively to seed priming and line sowing. The wheat variety WK 1204 is highly productive compared to local variety and suited for the climate of mid hills. Grain yield is significantly increased by treating the seeds organically before sowing them in the field. Reduced plant population (increased spacing 20cm x 8cm) is crucial for increasing the number of tillers per plant, plant height and spike length as well as number and size of grains resulting in higher grain and biomass yield. The average grain yield can be increased by 91.33% with adoption of SWI technology compared to local practice. Based on above results, following recommendations are made:

1. SWI in 5 Ropani of land with improved variety, seed priming and line sowing can increase as much as 100% yield, which can contribute for attaining food security for more than 6 months for a 6 member household assuming the consumption rate as 4 kg/day.
2. The tediousness for line sowing and weed problem can be minimized by introducing simple manually operated women-friendly seed-driller and cono-weeder which are cost-effective and successfully used in our neighboring Indian state of Bihar.
3. If only improved seed is available, then seed priming with broadcasting method can also increase crop yield.
4. Use of Farm Yard Manures (FYM) is vital in maintaining the soil fertility status.
5. Commercial-orientation of Farming As A Business (FAAB) training should ensure market system development like inputs availability at local level for long term sustainability of the production system.
6. SWI maximizes the labor factor productivity utilization in the marginal lands.
7. Seed treatment with mixture of jaggery, cow urine and vermicompost increases the soil fertility by the action of non symbiotic biological nitrogen fixing agents in soils.

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