



The System of wheat intensification: A Novel approach for sustainable agriculture with increase wheat yield in low input methods.

¹Suvarna Namdeo, ²Chandra Kant Sharma

¹Assistant Professor, ²Head of Institute

¹SAGE University ,Indore,

²SAGE University Indore

Abstract

System of wheat intensification (SWI) is a novel wheat production technique with management of seed treatment, seed rate, spacing, weeding, irrigation, and use of nutrient. SWI with traditional method of wheat sowing was compared under the yield prospect. SWI allow seed treatment as compared to traditional method of wheat sowing, seed treatment enhance number of tillers, number of grains in spike and also increase grain weight as compared to untreated seeds. In Traditional method of wheat sowing involves closer spacing as compare to SWI used Wider spacing between plant to plant and row to row sowing with proper plant density allows proper aeration, moisture and nutrient availability in rhizosphere which enhance proper root development in early stage of crop growth. It is very useful for small and marginal farmers to directly enhance production and increase income with reduce food insecurity. SWI a innovative approach that can sustain agriculture with use of organic manure instead of chemical fertilizer. Recommendation of SWI can enhance productivity and profit of the economic poor farmers by saving agro inputs.

Key words: Traditional, Food Security, Seed Inoculation, Sustain Agriculture, System of Wheat Intensification.

Suvarna Namdeo¹, Chandra Kant Sharma²

1. Assistant Professor Institute of Agriculture Sciences, SAGE University ,Indore MP 452020
2. Head of Institute ,Institute of Agriculture Sciences, SAGE University ,Indore MP 452020 , ck21sharma@gmail.com

Introduction

Wheat (*Triticum aestivum* L.) is most important cereal food crop, its first in India both in area and production of the grain crops and second in world after China in production. It can be grown from below sea level to 5000 m altitude and in areas where rainfall ranges between 300-1130 mm. Due to its contribution more protein and more calories to the worlds diet its very popular compare to other food crop. Subtropical region of India contribute major wheat area. Wheat crop growth is very productive in cool and sunny winters. Wheat occupies about 32% of the total acreage under cereals in the world. The wheat is cultivated throughout the year in one or the other parts of the world. The main wheat growing countries include China, India, U.S.A., Russia, France, Canada, Germany, Turkey, Australia and Ukraine .In India during 2018-19 area under wheat cultivation was 29.14 million hac (15.23

%) production 102.19 million tones and yield 35.07 q/per hectare, now comes in condition with Madhya Pradesh : it stands third position in area after U.P and Punjab (Fig.- 1) , in M.P area was 29.14 million hectare, which was 15.23% of total area of India, production was 15.47 million tonnes, Which was 15.14 % of Total Production of India. (Source- Directorate of Economics and Statistics, New Delhi Dept. Of Agriculture and Cooperation and Farmer welfare, Govt. of India). The system of wheat intensification (SWI) method has a great potential to enhance wheat productivity and production, It provide good growing condition through modified soil, water, sowing method, nutrient management. SWI give 54% more yield than available best conventional sowing practices (Uphoff *et al.*, 2011, Adhikari, 2012) and give a better economic return (Raol, 2012). System of wheat intensification is based on the principles of SRI (system of rice intensification) being practiced in paddy. This is a new wheat cultivation technique in which seeds are sown by maintaining plant to plant and row to row distance at 25 cm., this kind of sowing with proper spacing allows for sufficient aeration, moisture, and availability of nutrients leading to proper and healthy root development from the early stage of crop growth till the harvesting stage . SWI is the intensive care in every stage of plant growth and alter agronomic practices like lower seed rate, seed treatment, and effective management of water and inter cultivations practices, which result in higher no. of tillers to parental seedling, increased number of effective tillers per hill, enhance panicle length and bolder grains and finally enhanced yield of wheat. In the conventional system, farmers use about 100-140 kg/ha of seed but in the SWI method seed requirement is only 5%-7.5% of this amount (Styger and Ibrahim, 2009). A proper ratio of organic and inorganic inputs of nutrient is necessary for an efficient agriculture (Reganold *et al.* 1990). The crop requires mild temperature at the stage of maturity, but in those areas terminal heat stress occurs which reduces duration of grain development and consequently the grain yield (Mukherjee, 2012). Although direct seeding is the common practice in wheat cultivation, but seedling transplanting has been adopted in some areas of India. The objective of the review work was to merge the findings and hypothetical results, finally got a result whether the SWI did increase yield potential of wheat crop to an extraordinary degree. SWI is one of the promising technologies to increase productivity which ultimately contributes to the household level of food security of marginal farmers. SWI method was initiated in India by some community workers on fields of small and marginal farmers in 2006 and their encouraging results paved the path of systematic research among the farmers, (Anil Kumar *et al.* 2015). SWI has been tested as innovative approach to increase productivity and being practiced in MP at Chhindwara, SWI is evolving and being tested in many places of MP. The promotion of SWI has shown very good results in combining hunger among marginalized and small farmers. These technologies area unit presupposed to cut back the dependency of the farmers on multi-national firms for seeds, fertilizers or for his or her livelihoods, (Rout et al. 2010). The most objective of this extension work is to match the yield from ancient follow of sowing therewith of SWI, so it'll be technically effective and possible, economically viable, socially acceptable and environmentally sound for the wheat production. Results has sown that grain yield of wheat is increased by double of previous yield at its maximum, with adoption of this technology. Spacing between row to row and plant to plant 25 cm, use of organic manure and organic seed treatment ensures higher yield. Sufficient spacing between the plants and sowing of 2 germinated seeds 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 cycle hand wheel hoe save time and expenses on labour.

System of Wheat Intensification (SWI)

System of wheat intensification is follow the principle of system of Rice intensification .If we discuss about condition of Rice –Wheat cropping system in north India approx 10 million hectare area covered by this cropping system. It is possible only by using rigorous inputs like vigorous seeds, inorganic fertilizers, weedicide, Insecticide, Pesticides etc.If these inputs are not used proper and balanced; it might cause detrimental effect on environment, soil rhizosphere as well as on production and productivity of land. For intensify wheat production and productivity, SWI is great approach to now scenario. The system of wheat intensification has high probability to contribute enhance wheat production in per single unit of water and per kg of farm resources like seeds , inorganic

and organic fertilizer etc. ,and also follow the principle of SRI technology of Rice production (Dhar *et al.*, 2014). SWI and some modified SWI implementing activities may give 54% more yield than accessible best traditional sowing practices (Uphoff *et al.*, 2011, Adhikari, 2012) and showed a economic benefits (Raol, 2012). The widespread system of wheat production requires more inorganic fertilizers and nearly 100-140 kg of seed per hectare. SWI uses only 25-30 kg of improved seeds in one hectare; spacing between row to row and plant to plant is 25 cm .Sufficient spacing between the plants and sowing of 2 germinated seeds 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 cycle hand wheel hoe save time and expenses on labour. Wheat yield for SWI direct seeded was 13% higher compared to the control. Substantially improve with SWI was achieved in labour and water productivity. Labour requirement for SWI was reduced by 35-40% compared to the control. The return to labour (wheat produced per unit of labour) under SWI SD increased by 74% over the control. The other cause for higher potential under SWI might be associate to the intransigence to abiotic accent, less economic possibility and higher crush out turn (Satyanarayana *et al.*, 2007). Styger (2009) Uphoof (2012) in his booklet summarized the results from wheat sown under SWI. in farmers field reported that a 30% water saving is observed in SWI in comparison with conventional method of sowing (Uphoof (2012) . The results of this examine that height of plant, tillers number / hill, number of effective tillers, length of panicle , and production were establish higher in SWI method. In SWI, Line sown and broadcast practices, 2.6, 2.4 and 2.3 kg/4 m² , Yield was found respectively of wheat variety (Bhirkuti) . Chopra and Sen (2013) reported grain yield of wheat similarly in comparison with broadcast method of sowing .the result of experiment conclude that the yield by SWI method is more than conventional method. Bhargwa *et al.* (2016) suggested the adoption of SWI method by maintaining appropriate plant spacing and nutrient management could greatly enhance wheat production particularly in all regions of Madhya Pradesh, it is also recommended by him SWI method of wheat cultivation is more admirable than traditional method of wheat cultivation with revised endorsed methods and also admirable for farmers. Abraham *et al.* (2014) reported an increase of 18-67% grain and 9-27% straw yield of wheat at farmer's field in SWI as compare to broadcast method, as well as the outcome of many observation shows that this object .

SWI could be a viable option to address the following issues of present day agriculture.

Lack of good quality irrigation water : Integrated water management is basic principle for water management practices, which depend upon cautions use of good quality water and homogenous use of water , for alleviate this situation ,SWI can be adopt with higher water use efficiency .

Requirement of mitigating the effect of climate change: Rising of temperature is day by day is main reason of low production of wheat which is predictable due to decreasing in growth period. It is anticipate that both area and production of wheat is decreased day by day due to plicate of CO₂ and diffusive temperature of India is increased by 3°C. (FAO 2012). For conquer the effect of climatic changes, SWI can be help with proper sowing time, seedling procedures, surface debris detainment for temperature restraint and water sustentation.

Targeting the low productivity areas: Wheat production is very low in Eastern part of India as compare to other part of India. On the basis of statistical data, wheat yield of eastern part of India is 1.30- 2.78 t/hac, as compare to yield of dominant wheat production states such as first one is Punjab 4.72t/hac and second one is Haryana 4.45 t/hac. On the basis of data, production of wheat can be increased by using SWI method in place of traditional method of wheat cultivation in eastern part of India.

Production technology for dry lands : If we discuss about dry land farming so observe that rainfed agriculture contribute about 55% of the total sown area which is covering 78 million hac (NRAA 2012) area in India and 40% of the total food production (Ravindra Chary *et al.*, 2012). The dry land agro farming is impacted by abnormal weather condition, deterioration of soil, small farmers, low assets farmers etc. And interconnection of these factors (Ravindra Chary *et al.*, 2012). This limitation should be focus for structured and constructive uses of sparse assets which are obtainable under these conditions for expanding more efficient and effective technology for dry land

agriculture. It's observed that in these areas if moisture is conserved by SWI production technology, wheat production can be increased (Mishra *et al.*, 2007)

Principles of SWI

Principle of Root Development

It is observed that root play very important role for growth and development of any plant .If we discuss about conventional methods of wheat production, sowing of seeds are very close due to closer spacing roots compete each other for water, nutrient requirement and sunlight, it is also observed that closer spacing promotes more density of weeds, due to more population of weeds, they competitive each other and crops for nutrient (Kaur *et al.*, 2012) . In closer spacing root growth also inhibited, due to inhibition of root growth crop is not able to stop the growth of emerging weeds in the cultivated lands. it is also observed that due to closer spacing and growth of emerging weeds , root system is not develop properly and it is effect on tillering capacity of crop which is decreased by 41.6 % and also biomass yield is loosed 60-65 % in Lahore (Pakistan) , Anjuman and Bajwa (2010). But in SWI Method , spacing is maintain ,plants are grow in wide spacing that is 20 *20 cm and follow square pattern. Square pattern or wider spacing give higher wheat yield also creates border effect on the field. In square planting weeds are growing in field horizontal directions, which accomplish for raise soil aeration (Satyanarayana *et al.*, 2007).

Principles of Intensive Care:

Competition with weeds for nutrients, Nutrient deficiency, insects- pests and diseases are major drawback for higher production of wheat (Kaur *et al.*, 2012). For solving these problems some intensive principle applied in cultivation of SWI method which is based on SRI technology of rice (Dobermann, 2004; McDonald *et al.*, 2006) .

- Seed treatment for grooming of seeds.
- Plants are planted in square pattern with wide and uniform spacing which is from 20*20 upto 50*50 cm.
- Conoweeder used for control the weeds in place of weedicide and manual weeding.

Production Technology For SWI

Based on the above principles the System of Wheat Intensification involves the following modified practices for achieving higher productivity (according to Ram Bahadur Khadka and Prashanta Raut)

Seed Treatment: Seeds are treated with Bavistin or Vitavax to control seed borne fungal diseases. Also seeds are treated with organic mixture of well decomposed compost, jaggery and cow urine for increased microbial activity in the soil.

Procedure for Seed Treatment:

- 10 liter of hot water (60 degree Celsius) take in an earthen pot and dip 5 Kg of pure seeds in hot water .
- Seeds which float on the water, remove it.
- After that take, 2 kg of jaggery, 3 liter cow urine and 2 kg FYM and mix well properly with seeds.
- Then remain the material placed for 6-8 hour in shade.
- Then seeds separated with solid materials and liquids after 6-8 hopur
- After that 10 gm fungicide mix with seeds and remain for 10-12 hrs.
- After the germination of seeds, it should be used for sowing purpose.

Land Preparation and application of Organic Manure: First step of land preparation is applied Organic manure at the rate of 10 quintals per ropani and incorporated in the soil by ploughing. Loss of nutrients through leaching and evaporation is due to farmers assemble organic manure in open field for months, before final land preparation. SWI helps to improve the soil health in addition to providing nutrients to the crop.

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

Line Sowing: it is very important that Maintaining plant to plant distance for proper root development and tillering in wheat crop. For that two seeds are sown per hill and spacing is between row to row and plant to plant at 20 cm x 20 cm. using seed drill seeds should be sown at a depth of 2.5 – 3 cm. Moisture availability in the field is very important for germination of seed.

Gap Filling: If the seeds have not germinated, within 10 days of seed sowing the gap in this remaining place re-sowing should be done with germinated seeds. If two seeds germinated in one hill they should be uprooted to enhance proper growth of the plant.

Irrigation : After 15 days of sowing, root initiation starts, during this time first irrigation is given. Unavailability of moisture in soil inhibits root initiation. Second irrigation is given when tillers start emerging that is 25 days after sowing. After 35- 40 days sowing third irrigation is given. After at 60, 80 and 100 DAS, subsequent irrigations are given. Appropriate moisture should be available in the soil during the flowering and grain-filling stage.

Weeding: Hoeing and weeding should be done after the first, second & third irrigations by using the conoweeder. It helps to detach the soil as well as it makes the field free from weed. This practice increasing the soil aeration in the root zone and enhances the root length. This helps in emerging forth more tillers in the plant with more vigour.

Crop Rotation with legumes: wheat rotation with legumes like soybean and pulses will help to improve productivity of wheat by improves nutrient level in the soil and improving soil productivity. Wheat crop yields enhance by rotation with legumes because legumes help to fixation of nitrogen in soil and improve soil fertility and productivity.

Management of Organic manure/FYM : If we used organic manures for the fulfil the nutrient requirement, it release nutrients slowly, in small proportion but without change continuously. So, nutrients are available for a longer period of time. Also increase the microbial activity in soil, FYM is very effective way of manuring. Following points should be considered for proper compost making:

- Protection from rainwater is very important in case of FYM because it leaches the nutrients.
- For the prevent volatilization of ammonia it is ensure that FYM should be protected from sunlight.
- Cattle urine should be collected and utilized properly.
- FYM should be mixed in the soil properly

(According to Lalita Rana et al., 2017) SWI is based on principle of SRI (System of rice intensification).As the SRI technology SWI also required vigorous seed and specific agronomic field management practices. Cultivation practices for SWI has given below.

Land preparation: For land preparation it is required that before 15- 20 days of sowing 0.4t vermicompost or 2.0 t FYM per acre should be mixed well in land. Ploughing is also important aspect before sowing if moisture is not present in soil ,for fulfil the requirement of nutrient 27 kg DAP and 13.5 kg potash per acre should be broadcast before the last ploughing. It is observed that for fulfil the demand of both organic and inorganic fertilizer in the time of field preparation can be estimated by nutrient decision support systems such as “Nutrient Expert[®]” (Majumder *et al.*, 2014).

Selection of seed: seed should be vigorous in nature, free from seed of other variety and weeds seed. Seed variety should be selected according to their climatic condition. Always certified seeds should be used from an authentic source like Krishi Vigyan Kendra, state seed corporation etc.

Seed treatment: The following things are necessary for seed treatment:

- Vigorous seed: 10 kg
- Hot water (60°C): 20 liters
- Vermicompost: 5 kg
- Jiggery/ gur (Molasses): 4 kg
- Cow urine: 4 liters
- Fungicide (Bavistin) : 20 g

Seed treatment process:

According to PRADAN (2012) the following steps should be applied .

- Take 10 kg vigorous seed which is free from foreign material.
- Then seed dip into 20 liters warm water (60°C)
- After that separate all seed which float on the top of water.
- Then vermicompost, gur and cow urine ; 5 kg, 4 kg and 4 liters add continuously with seed, then mixture remain as it is for 8 hours.
- After 8 hours seed separate from the mixture solution.
- After that 20g Bavistin mix with seed and take rest for 12 hours in a jute bag, it is secure that jute bag should be wet, because moisture is important for germination.

Time of seed sowing: sowing time is a very important factor for wheat production .wheat sowing time is different according to its producing areas ,many factors which effect on time of sowing like that soil temperature, moisture availability in soil and growing time period of wheat varieties.

Method of seed sowing: It is ensure that proper moisture present in soil when seeds are sown in germinated condition. For proper growth and development of plant, maintain spacing between two seeds should be 20 cm. and per hill two seeds are sown. Gap filling also required within 7 days, when seeds are not germinate properly and uniform.

Irrigation: Stage-wise irrigation management practices should be as Apply -

- At 15 DAS (days after sowing) First Irrigation is given which activate root initiation. Because, moisture deficiency in soil will avert root initiation.
- At 25 DAS Second irrigation is done, which increase in come out tillers in more numbers .
- At 35-40 DAS Third irrigation is given.
- At 60, 80 and 100 DAS Succeeding irrigations are given, which is depend on soil and climatic conditions.
- Pertinent moisture availability in soil throughout flowering and grain – filling stage is very necessary for proper growth.

Nutrient Management: Stage –wise Nutrient application should be as apply -

- Organic and Inorganic both nutrients are applied after the first and third irrigation.
- As a organic fertilizer 4q vermicompost and as a inorganic fertilizer 40 kg urea per acre are applied after the First irrigation.
- For fulfill the requirement of remaining nitrogen and potash fertilizer, 15 kg urea and 13 kg potash per acre applied after the third irrigation.

Weeding: For producing more numbers of tillers/plant, it is necessary that weeding should be done stage wise.

- First weeding is require after 15-20 DAS or after first irrigation.
- Hoeing and weeding should be done with each irrigation for weed free field.
- Another purpose of weeding is loosening of soil which is necessary for the proper aeration in root area and elongation of root length.

Table 1 SWI at a glance.

S.No.	Modified practices	Expected outcome
1.	Decreasing seed rate	ratio between tillers and mother seedlings in more than normal
2.	Seed treatment by fungicide	Effective numbers of tillers /hill increased
3.	seeds sowing at wider spacing	Increase length of panicle and healthy grains
4.	water management in control manner	Increase yield/ hactare
5.	Hoeing/weeding practices by using conoweeder	Competition between crop and weed is control in effective manner

Source: Modified from Sheehy *et al.* (2004)

Table 2 Comparison between traditional wheat cultivation and system of wheat intensification (SWI).

S.No.	Particulars	CONVENTIONAL CULTIVATION	SWI Method
1	Seed rate	100-125 kg/ha	20-30 kg/ha
2	Seed treatment	Not done	With cow urine, gur, and fungicide
3	Sowing Method	Broadcasting	Line sowing with wide spacing
4	Spacing Between plant	No spacing	20 cm × 20 cm to 50 cm × 20 cm
5	Hoeing	Not done or by herbicide	3 times through the conoweeder
6	Panicle Length	10-11 cm	15 cm
7	grains/panicle in Number	18-50	60-120
8	panicles/hill	Mostly 1-2, Good stand 2-4	20-45
9	Time of Emergence	7 days after sowing	2-3 DAS sowing
10	Width of leaf	Thin; Less leaf area index	Broad; More Leaf area index
11	Width of Stem	Thin	Thick
12	Depth of Root	Shallow root	Deep root (upto 8-10 inches)
13	No. Of Irrigation given	2-4 irrigation	4-5 irrigation
14	Yield per hectare	1 – 2 t/ha	3 – 4 t/ha

Source: ATMA (2008); PRADAN (2012)

Table 3 Yield character of wheat sown in SWI and conventional method

Parameters (average of 10 plants)	2013-14		2014-15		2015-16	
	Conventional	SWI	Conventional	SWI	Conventional	SWI
1. Number of Tillers	6	27	5	25	7	32
2. Grains/Spike	24.6	49.8	22.4	46.8	50.3	73.5
3. Number of spikes/ m ²	315	426	307	403	407	462
4. 1000 grain wt (gm)	53	68	50	61	54	76
5. Grain yield q/ha	31.9	57.3	30.6	54.8	32.8	61.3
6. Straw yield q/ha	5.4	7.4	5.0	6.9	5.9	8.12

Chanchal Bhargava *et al.*

Practice of SWI in different parts of the world

Since 2006, Institute of Yanjiang Agricultural Sciences in Jiangsu working together with Centre for Agro-ecology and Farming Systems of the China Academy of Agricultural Sciences on SWI, and suggested that SRI Principle can be adopted for wheat-rice cropping system. This suggestion is adopted by Indo-Gangetic Plains of South-Asia and also by China.

Since 2010 SWI also experimented in Doti, Dadeldhura, Baitadi and Kailali districts of western Nepal in farmers land with the help of two NGOs first one is Mercy Corps Nepal and second one is FAYA-Nepal. On the basis of this experiment, it's observed that SWI express 91-100% more yield as compare to conventional method of wheat cultivation.

Since 2011-12, SWI is also demonstrated with some modified Technology in Sindhuli district of Nepal in farmer field as a farmer field school. Which give more production and economic come back. They observed that under same situation of farm inputs like water management, nutrient availability etc., Bhirkuti variety of wheat used for demonstration, which given 54% more production as compare to traditional method of sowing. On the basis of demonstration, SWI given 6.5 tonnes/hectare more yield as compare to yield of broadcasting method and line sowing which is 3.7 tonnes/ha and 5 tonnes/ha continuously.

Practice of SWI in different states of the India

In 2006 SWI was first demonstrated in northern India farmers which are working together with the People's Science Institute (PSI). These results are very impressive; due to these results PSI encouraged SWI and promote in the 2 other states first one is Uttarakhand and second one is Himachal Pradesh. Uttarakhand and Himachal Pradesh was adapted SRI Concept for wheat production and demonstrated first trial which is based on SRI (System of Rice Intensification), PSI started work under the financial support of the NABARD in during winter 2006-2007, PSI is a NGO which is present in Dehradun (Relkar 2011). SWI is also introducing in Bihar state by the Aga Khan Rural NGO with different aspects but still favourable results. In other parts of India, It reported that SWI yield increases less than just 32%, with farmers averaging 3.48 tonnes/ha instead of 2.63 tonnes/ha with usual practices. Several districts of Uttar Pradesh and Madhya Pradesh is given good farmer response and results in SWI method. These states has been encouraged by PSI since 2010. SWI method was initiated in India by some community workers on fields of small and marginal farmers in 2006 and their encouraging results paved the path of systematic research among the farmers, (Anil Kumar *et al.* 2015). SWI has been successfully promoted by many agencies like Pradhan (2014), an NGO in MP, and agriculture technology management agency (ATMA) of Govt. of India, Peoples Science Institute (PSI) another NGO in

Uttarakhand (2015) in India and USAID in Mali (2012). SWI has been tested as innovative approach to increase productivity and being practiced in MP at Chhindwara, These technical knowledge are supposed to depreciate the need of the farmers on multinational companies for seeds, fertilizers or for their, subsistence (Rout *et al.* 2010)

Conclusion

In conclusion, System of Wheat Intensification Method of wheat cultivation has shown positively response on all measured growth parameters, yield characters and yield production compared to conventional method. It shows positive response for seed treatment and wider space sowing. This review paper shows that close spacing 20cm x 8cm is crucial for increasing the number of tillers per plant, plant height and spike length. Wider spacing 25cm x 25cm is increase no. of tillers per plant and inhibit growth of weeds, if seed are treated in organic way like mixture of jaggery, cow urine and vermicompost increases the soil fertility and Productivity due to reaction of non symbiotic nitrogen fixing bacteria in soils and it perform more germination and also increase in number of tillers per plant. SWI Method is more efficient and reliable in the case of mitigating the climate change, control use of irrigation and control of weeds in proper manner. As per data of different researchers, SWI Increase 18-67% grain and 9-27% straw yield of wheat at farmer's field as compare to broadcast method. Due to wider spacing SWI prefer low seed rate as compare to traditional method of wheat. Due to lower seed rate it is more economical for farmers. it reduce the cost of cultivation for example use conoweeder for controlling weeds as compare to manual hand weeding, conoweeder are cost effective, easily operated and successfully used now a days in India. So SWI is very reliable and economically good for small holding farmers.

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