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System of Wheat Intensification: An Innovative and Futuristic Approach to Augment Yield of Wheat Crop

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ABSTRACT

There is a new method of wheat production called the System of Wheat Intensification (SWI) that manages seed treatment, seed rate, spacing, weeding, and watering. The SWI and traditional methods of wheat sowing differ from each other in terms of potential yield. In comparison to the traditional method of wheat sowing, SWI allows seed treatment, which increases the number of tillers, the number of grains in spike, and the weight of the grain. Wheat seeding in the traditional approach is done at a much closer distance than in the SWI method, which results in faulty germination as a result of increased competition between the plants. In SWI, proper root formation in the early stages of crop growth can be encouraged by increasing the space between plants and rows, as well as increasing the density of plants. For small and medium-sized farmers, it is a great way to boost productivity and income while reducing food poverty at the same time. Using organic manure instead of chemical fertilizer is a new strategy that helps support sustainable agriculture. To help the poorest farmers and enhance their productivity and profit, SWI should be recommended.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most significant cereal food crops, ranking first in India in terms of area and production of grain crops and second in the world in terms of production after China. It may be grown from below sea level to 5000 m altitude and in regions with 300-1130 mm of annual precipitation. The subtropical region of India is mostly responsible for the country's wheat production. Winters that are cool and sunny are ideal for wheat crop growth. Wheat comprises around 32 percent of the world's cereal-growing acreage. Wheat is cultivated throughout the year in many regions of the globe. China, India, the United States of America, Russia, France, Canada, Germany, Turkey, Australia, and Ukraine are the leading wheat-producing nations.

In India during 2020-2021, the area under wheat cultivation was 31.61 million hectares with production of 109.52 million tones and a yield of 34.64 quintals per hectare. Punjab now occupies the third position in terms of area, after Uttar Pradesh and Madhya Pradesh. In Punjab, the area was 3.53 million hectares, which was 11.15 percent of India's total area, and production was 17.14 million tonnes (Agricultural Statistics at a Glance 2021).

The system of wheat intensification (SWI) method can significantly increase wheat productivity and yield. It provides favorable growing conditions by modifying soil, water, sowing methods, and fertilizer management. SWI gives a 54 percent greater yield than the best available conventional sowing techniques (Uphoff et al. 2011, Bhargava et al. 2016, Raghavendra et al. 2019, Adhikari 2013), which can, in turn, give a higher financial return (Raol 2012). This is a new method of wheat cultivation in which seeds are sown with a plant-to-plant and row-to-row distance of 25 centimeters. This type of sowing with proper spacing allows for sufficient aeration, moisture, and nutrient availability, resulting in proper and healthy root development from the early stages of crop growth till harvesting. SWI is the application of intensive care at every stage of plant development and the modification of agronomic practices, such as a lower seed rate, seed treatment, and effective management of water and inter-cultivation practices, which results in a greater number of tillers to parental seedlings, a greater number of effective tillers per hill, an increase in panicle length and bolder grains and ultimately an increase in wheat yield. In the conventional approach, farmers use approximately 100-140 kg.ha^{-1} of seed, but the SWI method requires only 5%-7.5% of this quantity (Styger & Ibrahim 2009). An optimal ratio of organic to inorganic nutrient inputs is required for productive agriculture (Reganold et al. 1990). The crop requires moderate temperatures during the maturation stage, but in certain regions, terminal heat stress affects the duration of grain growth and, consequently, grain production (Mukherjee 2012).

The use of this technique has resulted in a doubling of wheat's maximum grain production compared to its prior maximum output. Appropriate spacing, usage of organic manure, and organic seed treatment all contribute to a greater yield. A sufficient distance between plants and the seeding of two germinated seeds at a single location facilitates the appropriate moisture, aeration, nutrition, and illumination of the crop roots. This promotes faster plant development. Only two to three cycles of watering and weeding using a hand wheel hoe save time and money on labor.

WHEAT INTENSIFICATION SYSTEM IN RELATION TO CONVENTIONAL WHEAT SOWING METHOD

Approximately 10 million hectares of land are covered by the Rice-Wheat cropping system in northern India if we consider the current status of this system. It is only achievable via the use of rigorous inputs such as robust seeds, inorganic fertilizers, weedicides, insecticides, and pesticides. If these inputs are not used properly, and in balance, they may have a negative impact on the environment, soil rhizosphere, as well as on the output and productivity of the land.

The system of wheat intensification is based on the system of rice intensification. SWI is an excellent strategy for intensifying wheat production and productivity in the current situation. The system of wheat intensification has a high likelihood of contributing to an increase in wheat output per unit of water and kilogram of agricultural resources such as seeds, inorganic fertilizer, and organic fertilizer. Also, it adheres to the SRI technology of rice cultivation (Dhar et al. 2014). Uphoff et al. (2011) and Adhikari (2012) found that SWI and some modified SWI implementation activities may result in a 54 percent increase in yield compared to the best accessible conventional sowing approaches and may have economic advantages (Styger 2009). Widespread wheat cultivation requires more inorganic fertilizers along with a seed rate between 100 and 140 kg of seed per acre as indicated in Table 1. In contrast, SWI utilizes just 25-30 kg of modified seeds per hectare having row-to-row and plant-to-plant spacing of 25 cm (Raol 2012). One of the other reasons for potential yield under the SWI system is resistance to abiotic stress, a decrease in input requirement rate, and an increase in financial possibilities (Satyanarayana et al. 2007).

SWI saves 30 percent more water than the typical way of sowing, according to farmers' field reports (Uphoff 2012). The height of the plant, number of tillers per hill, number of effective tillers, panicle length, and yield were determined to be higher using the SWI approach. In SWI, line sown, and broadcast methods, the wheat variety (Bhirkuti) yielded 2,6, 2,4, and 2,3 $kg.m^{-2,}$ respectively. Chopra and Sen (2013) showed a similar correlation between wheat grain production and the broadcast technique of planting. The results of the trial indicate that the SWI approach produces a higher yield than the conventional method as presented in Table 2.

Bhargava et al. (2016) claimed that the implementation of the SWI technique by maintaining adequate plant spacing and nutrient management might significantly increase wheat yield, particularly in all regions of Madhya Pradesh. Bhargwa himself also recommends the use of the SWI method. The SWI technique of wheat cultivation is preferably more beneficial to farmers as compared to the conventional method. Abraham et al. (2014) observed a rise of 18-67 percent in grain production and a 9-27 percent in straw yield of wheat at the farmer's field in SWI compared to the broadcast technique. The results of several observations indicate that this method was effective.

NECESSITY OF SWI IN THE PRESENT SCENARIO

SWI is required primarily to provide high wheat yield per unit of inputs/resources. SWI is important in light of the need for a retooling of food grain production, particularly wheat, to fulfill the growing population's needs. The continuous, excessive, and unprofessional use of synthetic agrochemicals results in soil and environmental damage. Additionally, there is a steady reduction in crop responsiveness to inputs,

Table 1: System of wheat intensification at a glance.

Serial number	Modified practices	Expected outcome
1.	Lowering seed rate	The tillers and mother seedling ratio is higher as compared to normal
2.	Treatment of seeds using fungicide	The number of effective tillers/hills improved
3.	Sowing of seed at a broad spacing	The length of the panicle is increased, and healthy grains
4.	Management of water in a precise manner	Yield per hectare is increased
5.	Performing intercultural operations like hoeing and weeding using Conoweeders	The conflict between weed and crop is controlled efficiently.

Source: Sheehy et al. (2004)

Table 2: Comparative studies between conventional wheat cultivation and SWI.

S.No.	Conventional cultivation	SWI Method
1.	The seed requirement is 100-125 kg/ha	The seed requirement is only 20-30kg/ha
2.	The seed treatment is usually not done	Seed treatment is done with fungicides, Cow urine, and Jaggaery (GUR)
3.	The method of sowing is broadcasting	Generally, line sowing should be done with broader spacing
4.	No plant-to-plant spacing is maintained	Spacing of 20cm X20cm to 50cm X20 cm is maintained
5.	No intercultural operation is done to uproot the weeds	Weeding/hoeing should be done with Conoweeders
6.	The length of the panicle should be 10-11 cm	The length of the panicle should be 15 cm
7.	The number of grains per panicle ranges between 18-50	The number of grains per panicle ranges between 60-120
8.	The number of spikes per hill is 1-2 in normal stand and 2-4 in good stand	The number of spikes per hill is 20-45
9.	The time of emergence is generally one week after sowing	The time of emergence is generally 2-3 days after sowing
10.	Leaf width is thin with a lesser leaf area index	Leaf width is broad with more leaf area index
11.	The width of the stem is thin	The width of the stem is thick
12.	The depth of the root is shallow	The depth of the root is deeper (8-10inches)
13.	The number of irrigations is 2-4	The number of irrigations is 4-5
14.	The yield is 1-2 tonnes per hectare	The yield is 3-4 tonnes per hectare

Source: ATMA (2008), PRADAN (2012)

especially in the setting of climate change. Intensive tillage, crop residue burning, loss of soil organic matter, degradation of soil fertility, loss of soil health, lack of high-quality and adequate irrigation water, salinity difficulties, arsenic concerns, etc., are additional significant problems linked with chemical agriculture. All of these factors result in stagnant wheat output levels. Under such conditions, SWI has promising potential, as it strives to increase wheat yield with minimal input costs and without compromising soil and environmental quality. In addition, it may be a viable solution for increasing wheat output in Eastern India's less productive regions. As SWI employs a method of alternating soaking and drying, it also has a promising future in arid regions Biswas and Das (2021).

MAJOR AGRICULTURAL CHALLENGES ADDRESSED BY SWI

Lack of high-quality irrigation water: Integrated water management is the foundational principle for water management practices, which rely on the careful use of high-quality water and the uniform application of water; to remedy this situation, SWI can be implemented with greater water use efficiency.

The imperative of mitigating the effects of climate change: The steadily increasing temperature is the primary cause of the declining wheat yield, which is expected due to the shortened growing season. Due to the doubling of CO_2 and a 3°C increase in India's diffusive temperature, it is expected that both the area and yield of wheat would continue to decline. (FAO 2012). For overcoming the effects of climate change, SWI may assist in determining the optimal sowing time, seedling operations, surface debris retention for temperature control, and water sustenance.

Focusing on low-productivity regions: Compared to other parts of India, the Eastern region of India has the lowest wheat output. Based on statistical data, the yield of wheat in the eastern portion of India ranges from 1.30 to 2.78 $t.ha^{-1}$, as compared to the yield of major wheat-producing states such as Punjab (4.72 $t.ha^{-1}$) and Haryana (4.45 $t.ha^{-1}$). Based on statistics, the output of wheat in eastern India may be boosted by utilizing the SWI technique instead of the traditional way of wheat farming.

Production methods for arid regions: When discussing dry land farming, it is important to note that rainfed agriculture accounts for around 55% of the total planted area in India, which is 78 million hectares (NRAA 2012), and 40% of the overall food output (Ravindra Chary et al. 2012). Dry land agriculture cultivation is affected by atypical weather conditions, soil deterioration, small farmers, farmers with limited assets, etc., and the interdependence of these elements (Ravindra Chary et al. 2012). This constraint should be the focus of organized and productive uses of scarce resources that are available under these conditions for the development of more efficient and effective dry land technology.

FUNDAMENTALS OF SWI

SWI is essentially founded on two crop production principles:

1. The fundamentals of root development
2. Fundamentals of intensive care

The Fundamentals of Root Development

For a plant's optimal growth, its root system should be well. Root development is the initial phase in a plant's proper growth and development. It demands enough nutrition and adequate space surrounding the plant, which is essential for crop growth and development.

The Fundamentals of Intensive Care

Increased frequency does not refer to a high number of plants per unit of area rather, it is the preservation of the space and noticeable care to the plants. To increase yield, intense care is required at every stage of plant growth, particularly weed, pest, disease, organic fertilizers, and irrigation management.

AGRONOMICAL/CULTURAL PRACTICES ADOPTED IN SWI

Modifications in sowing geometry, weed management, and an emphasis on organic manuring provide a favorable environment for crop growth in SWI (Fig. 1). Yet, the core principles of wheat agriculture remain relatively unchanged. It tries to boost agricultural yields while increasing the land's inherent productivity with little external inputs. SWI needs a number of stages for effective improvement in grain and straw production, including site assessment and anticipation, selection, and treatment of seeds, sowing, weed management, application of manure, and adequate water management. These procedures are briefly described below.

Site assessment and anticipation: Well-drained, loamy, rich soil with a pH between 6.0 and 8.5 is good for wheat growing. Resist saturated soils and choose land with a good drainage system capable of eliminating surplus water. Three ploughings are necessary to achieve a suitable tilth for wheat planting in SWI. The initial plowing is performed to remove the roots of previous crops grown in the area. After one to one and a half months, compost is added, and the soil is tilled again. The last tillage is performed before sowing wheat seeds.

Selection and treatment of seeds: Putting 20-25 $kg.ha^{-1}$ seeds in a 20 percent salt-to-water solution and removing the floating seeds yields robust and vigorous wheat seeds. Thus, for seed treatment, make a combination of 10 liters of hot water (60°C), 2 kilograms of well-decomposed compost or vermicompost, 3 liters of cow urine, and 2 kg of jaggery in a clay pot. After adequate mixing, 5 kg of seeds were dipped in the mixture and allowed for 6 to 8 h. With the same proportion of the aforementioned ingredients, a larger quantity of seed can be treated with the combination. The next step is to remove the seeds from the mixture using a filter and clean water. By the time treated seeds have been maintained in the shade for 10-12 h, they have fully sprouted.

Sowing: The sprouting seeds will be sown in the field using a dibble method with two seeds per hill. According to the moisture content, different row-to-row and plant-to-plant spacing (15 cm×15 cm or 20 cm×20 cm) can be utilized. For sowing, a manual or powered seed drill can be employed. If a seed drill is unavailable, the fields are marked at 15/20 cm intervals using rope or thread. Using a dibbler or pegs,

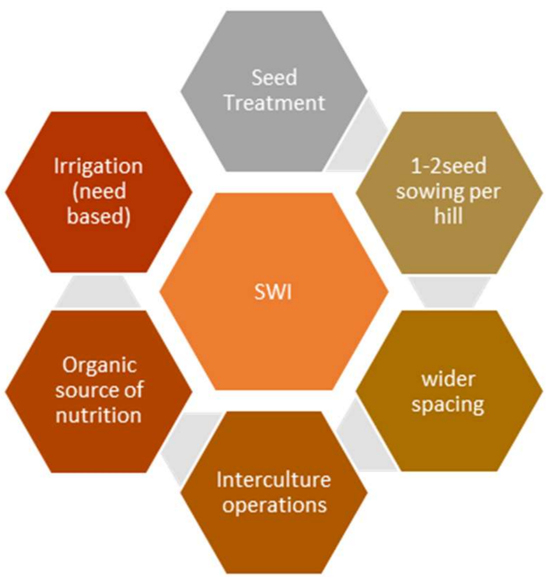

Fig. 1: Agronomical practices followed in the system of wheat intensification.

seeds will be planted at a depth of 2.5-3 cm. When sowing germinated seed, the soil must contain an adequate amount of moisture. Within 10 days of seeding, gaps were filled with germinated seeds wherever seeds failed to germinate or were eliminated. To limit competition, extra seeds grown on a hill have been removed.

Weed management: Hoeing is a crucial component of sustainable agriculture because it destroys weeds that compete with crops for space, light, and water. Hoeing of weeds softens the soil and efficiently oxygenates the roots, permitting exploration of the soil that leads to improved nutrient and water uptake from bottom soil. The incorporation of weeds into the soil increases the soil's water-holding capacity and nutritional status. In SWI, weeding is typically performed thrice, beginning 20 to 25 days after sowing (DAS). The successive weedings are performed 10 days apart.

Application of manure: A healthy wheat crop requires the right proportions of nitrogen, phosphorus, and potassium, i.e., 80-125:40-60:30-40 $kg.ha^{-1}$. To maintain a balance of vital nutrients, soil test-based nutrient recommendations are followed by the application of organic manures such as farm yard manure, vermicompost, NADEP (Narayan Deotao Pandharipande) compost, liquid manure like Panchagavya, Amritghol and Matkakhad (PAM) and other manures (such as agricultural residues and animal wastes are commonly used in practice).

Water management: In SWI, the soil is frequently made wet and dry, and 3-5 irrigations are provided based on soil moisture state. The initial irrigation is applied at 15 DAS before the crown root initiation (CRI) stage. After 40 DAS, a second watering will be done if the soil develops fine cracks. Irrigation is performed prior to weeding in the early stages of crop development. At 75 DAS, a third irrigation was provided. The fourth irrigation was administered during the blooming stage, while the fifth irrigation was administered during the grain-filling stage.

Pest and disease management: Varieties that are resistant to pests and diseases are chosen, and seed treatment can be performed before planting to reduce crop damage inflicted by biotic stress. SWI promotes the use of biological pest management methods, such as biological agents and organic pesticides.

Harvesting: Productive tillers/hills are the result of enough sunlight, water, and air circulation. With the appropriate implementation of the SWI package and practices, the crop develops on time and is reaped whenever the wheat grain's moisture content is between 20 and 25 percent as indicated in Table 3.

IMPLEMENTATION OF SWI IN THE WORLD

Since 2006, the Institute of Yanjiang Agricultural Sciences in Jiangsu has collaborated with the Centre of Agro-ecology and Farming Systems of the China Academy of Agricultural Sciences on SWI, recommending that the SRI Principle be implemented in wheat-rice cropping systems. China and the Indo-Gangetic Plains of South Asia have adopted this recommendation.

Since 2010, SWI has also tested in the western districts of Doti, Dadeldhura, Baitadiand, and Kailali with the assistance of two NGOs, namely Mercy Corps Nepal and FAYA-Nepal. Based on this trial, it has been shown that SWI produces 91 to 100 percent higher yield than traditional wheat farming.

Since 2011-12, SWI has also been exhibited in the Sindhuli area of Nepal on farmer fields with updated technology. Which increases output and economic return, and it was noticed that under the same conditions of farm inputs such as water management, fertilizer availability, etc., the Bhirkuti type of wheat utilized for demonstration yielded 54 percent higher than conventional planting. Based on the demonstration, SWI yielded 6.5 $tons.ha^{-1}$, greater than broadcasting and line sowing, which produced 3.7 $tons.ha^{-1}$ and 5 $tons.ha^{-1}$, respectively.

IMPLEMENTATION OF SWI IN INDIA

SWI was originally tested in India in 2006 by PSI (People

Table 3: Yield characters of wheat sown under SWI and conventional method.

Parameters	2013- 2014		2014-2015		2015-2016	
	Conventional	SWI	Conventional	SWI	Conventional	SWI
Number of tillers	6	27	5	25	7	32
Grains per spike	24.6	49.8	22.4	46.8	50.3	73.5
Number of spikes $/m^2$	315	426	307	403	407	462
1000 - grain weight [gm]	53	68	50	61	54	76
Grain yield $[q.ha^{-1}]$	31.9	57.3	30.6	54.8	32.8	61.3
Straw yield $[q.ha^{-1}]$	5.4	7.4	5	6.9	5.9	8.12

Source: Bhargava et al. (2016)

Table 4: Comparison of Cost of cultivation under conventional method of wheat cultivation and system of wheat intensification (SWI).

Particulars	Conventional	System of Wheat Intensification
A) Operations		
Ploughing	3000	3000
Seed	650	300
Weeding	0	1800
Irrigation	300	500
Fertilizers and plant protection chemicals	200	400
Harvesting and threshing	2000	2000
Total	6150	8000
B) Yield and income		
Grain yield (quintal/hectare)	6	10
Gross income @1100 per quintal	6600	11000
Straw yield (quintal/hectare)	10	16
Straw income@200 per quintal	2000	3200
Total gross income	8600	14200
Net income (Rs)	2450	6200

Source: Relkar (2011)

Science Institute) in North India using forty farmers in twenty-five villages, achieving a 66 percent increase in production above conventional approaches. Throughout 3 years, approximately 12,000 farmers in Himachal Pradesh and Uttarakhand adopted these new techniques. In Bihar, where 415 farmers, largely women, tested SWI techniques in 2008-09, a yield up to 3.6 $t.ha^{-1}$ was achieved in comparison to 1.6 $t.ha^{-1}$ using conventional procedures. In 2009-10, 15,808 farmers adopted SWI, yielding an average of 4.6 $t.ha^{-1}$. The SWI area in Bihar was reported to be 183,063 ha in 2011/12, with a yield potential of 4.5 $t.ha^{-1}$ as presented in Table 4.

Some community workers in India launched the SWI approach in 2006 on the fields of small and marginal farmers, and their good results paved the way for systematic research among farmers (Kumar et al. 2015). SWI has been evaluated as an innovative method for boosting production and is being implemented in Chhindwara, Madhya Pradesh (MP). SWI is evolving and is being evaluated in many other locations in MP. The development of SWI has yielded excellent benefits in reducing hunger among marginalized and small-scale farmers. These technologies are expected to reduce farmer's dependence on multinational corporations for seeds, fertilizers, and their livelihoods (Rout et al. 2010).

PROS AND CONS OF USING SWI

In SWI, the seed requirement is less (Only 20 to 25 $kg.ha^{-1}$), and it helps in seed saving up to (Seventy-five to eighty percent). It increases the number of efficient tillers in the wheat crop. Due to the modification of cultural/agronomical practices, crops should not suffer from lodging, which results in higher productivity. By adopting SWI, flowering and crop maturation are earlier. It results in excellent grain quality, and grains are long and lustrous. It produces a good amount of straw and makes the availability of more feed for livestock. There are fewer instances of pathogen and pest infestation. Weeding by conoweeder promotes healthy root aeration and significantly less water requirement, i.e., 20-30 percent. Improved germination percentage leads to more plant stands in the field is another benefit of SWI. SWI enriches soil fertility and helps in achieving sustainability. There are some major constraints to using SWI. For adopting the SWI technique, appropriate sowing tools are required.

Along with this, rigorous scientific study is required at all the research centers for the success of SWI. Cono-weeding is challenging on abrasive soil and is confined to male farmers only. In many locations, the supply of organic manures is occasionally limited, which 0is the other major challenge to adopt. Small-scale farmers cannot afford it sometimes, and there are insufficient extension services that can promote the SWI along with farmers.

CONCLUSIONS

SWI is a new aspect for increasing wheat output that can immediately enhance farmers' revenue and decrease their food shortages. It may help the crop to tolerate biotic and abiotic challenges that are intensifying as a result of climate change. By conserving agricultural inputs, the implementation of SWI can raise the productivity and profit of their source impoverished farmers. Wheat Intensification System, when compared to the conventional approach, showed a good response on all examined growth parameters, yield characteristics, and yield output. It has a favorable response to seed treatment and wider-area seeding. According to the findings of many researchers, SWI increases wheat grain production by 18-67 percent and straw output by 9-27 percent compared to the broadcast approach. Due to larger spacing, SWI prefers a lower seed rate compared to conventional wheat cultivation methods. Due to the reduced seed rate, it is more cost-effective for farmers. It reduces the cost of cultivation by using, for instance, a conoweeder to manage weeds instead of human hand weeding. Conoweeders are cost-effective, simple to use, and widely utilized in India today. SWI is highly trustworthy and economically beneficial for small-holding farmers.

REFERENCES

Abraham, B., Araya, H., Berhe, T., Edwards, S., Gujja, B., Khadka, R.B. and Verma, A. 2014. The system of crop intensification: reports from the field on improving agricultural production, food security, and resilience to climate change for multiple crops. Agric. Food Secur., 3(1): 1-12.

Adhikari, D. 2013. System of wheat intensification in farmers' field of Sindhuli, Nepal. Agron. J. Nepal, 3: 168-171.

Agricultural Statistics at a Glance. 2021. Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India (Website: http://www.dacnet.nic.in/eands)

Bhargava, C., Deshmukh, G., Sawarkar, S.D., Alawa S.L. and Ahirwar, J. 2016. The system of wheat intensification, in comparison with the conventional method of wheat line sowing, increases wheat yield with low input cost. Plant Arch., 16(2): 801-804.

Biswas, S. and Das, R. 2021. System of wheat intensification (SWI). Agric. Food. Newslett., 3(5): 175-178.

Chopra, R. and Sen, D. 2013. Golden wheat becomes more Golden - Extending SRI to wheat. LEISA India, 15: 30-32.

Dhar, S., Barah, B.C. and Vyas, A.K. 2014. Comparative Performance of System of Wheat Intensification (SWI) and Other Methods of Wheat Cultivation in North Western Plain Zone of India. Indian Agricultural Research Institute, New Delhi.

Food Agriculture Organization (FAO). 2012. FAO Statistical Yearbook 2012: World Food and Agriculture. Retrieved from http://www.fao.org (accessed 12th April 2015).

Kumar, A., Kumar, N., Baredar, P. and Shukla, A. 2015. A review on biomass energy resources, potential, conversion and policy in India. Renewable and Sustainable Energy Reviews, 45: 530-539.

Mukherjee, D. 2012. Effect of different sowing dates on growth and yield of wheat (Triticum aestivum) cultivars under the mid-hill situation of West Bengal. Indian J. Agron., 57: 152-156.

NRAA. 2012. Prioritization of rainfed areas in India (Study Report 4). National Rainfed Agriculture Authority (NRAA) Publication, New Delhi.

PRADAN. 2012. Cultivating Wheat with SRI Principle: A Training Manual. Bihar Rural Livelihood Promotion Society (BRLPS), the Agricultural Technology Management Agency (ATMA), and the NGO PRADAN, Nalanda, Gaya

Raghavendra, M., Singh, Y.V., Verma, R.K., Halli, H.M. and Goud, B.R. 2019. System of wheat intensification: An innovative approach. Indian Farm., 69(4): 456-472.

Raol, R.K. 2012. SWI Experience in Bihar. Aga Khan Rural Support Programme-India, New Delhi.

Ravindra Chary, G., Venkateswarlu, B., Sharma, S.K., Mishra, J.S., Rana, D.S. and Kute, G. 2012. Agronomic research in dryland farming in India: An overview. Indian J. Agron. 3rd IAC Special Issue, pp. 157-167.

Reganold, J.P., Robert, L.P. and Parr, J.F. 1990. Sustainability agriculture in the United States. In overview sustainable agriculture issues perspective and prospects in semi arid tropics. Int. J. Trop. Agric., 8: 203-208.

Relkar, P.M. 2011. System of wheat intensification (SWI). Tech. Dig., 13: 11-15.

Rout, N., B.S. Kumar, R.M. and Bajarachayra, M. 2010. Agricultural intensification: Linking livelihood improvement and environmental degradation in the mid-hills of Nepal. J. Agric. Environ., 11: 209-211.

Satyanarayana, A., Thiyagarajan, T.M. and Uphoff, N. 2007. Opportunities for water saving with higher yield from the system of rice intensification. Irrig. Sci., 25: 99-115.

Sheehy, J.E., Peng, S., Dobermann, A., Mitchell, P.L., Ferrer, A., Yang, J., Zou, Y., Zhong, X. and Huang, J. (2004). Fantastic yields in the system of rice intensification: the fact of fallacy? Field Crops Res., 88: 1-8.

Styger, E. and Ibrahim, H. 2009. The System of Wheat Intensification (SWI): Initial Test by Farmers in Goun-dam and Dire, Timbuktu, Mali, Africare, Mali, Bamako. Available at URL: http://ciifad.cornell.edu/sri/countries/mali/MaliSWIrpt071309.pdf (Accessed 23rd January 2015).

Styger, E. 2009. Sixty farmers evaluate the system of Rice Intensification in Timuktu. Available at URL: http//www.erikastyger.com/SRI_Timbuktu_Blog/SRI_Timbuktu_Blog. html. (Accessed 23rd January, 2015).

Uphoff, N., Kassam, A. and Harwood, R. 2011. SRI as a methodology for raising crop and water productivity: productive adaptations in rice agronomy and irrigation water management. Paddy Water Environ., 9: 3-11

Uphoff, N. 2012. Supporting food security in 21st century through resource conserving increases in Agriculture production. Agric. Food Sec., 1 : 18.