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System of Wheat Intensification Study using Hydroponically raised Wheat Seedling – A New Approach towards Farmer's Welfare

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Abstract: Wheat is 3rd most consumed crop in India after Rice and Maize. Its production is a source of employment for a major part of the country. Inspite of having such high demand Wheat Cultivating farmers faces problems like unavailability of irrigation water, poor survival rate, higher disease infestation, poor yields and unhealthy crop. In view of the same System of Wheat intensification (SWI) was expected to come out as a possible solution to these problems. In year 2017, Ayurvet Research Foundation, Chidana had conducted a field trial in which Hydroponically (soil- less method of raising crops) raised 8-day old Wheat seedling was transplanted through principle of SWI (through which fixed distance is maintained between 2 consecutive seedlings which facilitates proper root development and better yields). 4 treatments were practiced through which spacing of 10X10cm, 15X15cm and 20X20cm was maintained. Results showed direct yield gain of 18% (2311.1kg/acre) and 13% (2229.3kg/acre) in 10X10cm and 15X15 cm spacing as compared to conventional broadcasting method (1956.4kg/acre). The reason for not so convincing performance of 20X20cm spacing (1766.25kg/acre) was lower plant population though the highest seed weight of 32.5gm was recorded in 20X20cm treatment.
SWI is an efficient technology and can be of great help in doubling farmer's income. It had reduced weeding, use of pesticides and insecticides. Huge amount of water was saved because of the use of hydroponically raised Wheat seedling, germination rate was higher, survival rate was higher and the nutritive content of the seeds was way better than the conventional Wheat seeds.
Keywords: System of Wheat Intensification (SWI); Hydroponics; soil less technology; System of Rice Intensification (SRI); plant to plant spacing.

1. Introduction

In India Wheat is one of the most imperative crops, and stands second in grain production in the world next to rice (Meena, 2013). 55% of overall world's population depends on Wheat for the intake of about 20% of the food calories. Wheat plays an important role in country's economical and nutritional security. In India Wheat is an important staple food crop with an annual production of 93.5 m tones (13.6% of world Wheat production) covering 29.9 million ha area (FAO, 2014). About 98% of India's total Wheat production comes from Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Maharashtra, Gujarat, West Bengal and Uttarakhand (DES, 2014) whereas states like Bihar and Odessa stands far behind. It can be grown in the areas where rainfall ranges from 300-1130mm.

Productivity gains to the farmer from Wheat yields obtained from following traditional practices are diminishing from the past few years (Ray,2013). Farmers are facing low productivity because of certain other factors like weather (low and high temperature stress, high relative humidity and drought), soil factors (soil texture, soil pH, EC and available nutrients), water supply, availability of inputs like quality seed, irrigation, fertilizers also but technologies which are being followed still plays a crucial role. (Shiva Dhar et.al, 2015). Small and marginal farmers often complains about the high input cost that they need to invest for adopting hi-tech technologies for increasing their productivity .In view of the above alternative crop establishment methods are required which could cope up with these emerging problems i.e., gives higher yield at less cost, low water requirements and which can resist both biotic and abiotic stresses. One such methodology which can help in

driving such benefits is practiced in rice, namely System of Rice Intensification (SRI) (Stoop. et.al. 2002). Production strategies of SRI are widely used in Wheat as well and popularly known as System of Wheat Intensification (SWI).

What Is System of Wheat intensification (SWI)?

SWI is an innovative concept for Wheat cultivation. This technology facilitates manipulated soil environment for better root and shoot growth. This technology was developed on the basis of the results obtained from system of Rice intensification trial. In this method (SWI) wide row to row and plant to plant spacing (10cm-25cm) was maintained . Spacing provides sufficient aeration, proper light, moisture and reduced competition for nutrient leading to better roots and shoot growth. The tolerance power of the plants towards water stress, flooding, drought and lodging increases because of better roots, higher number of tillers and stronger tillers. The weeding percentage reduces significantly. Some studies suggested that herbicides which can be used as an alternative of Weedicides are highly effective in SWI fields. Level of disease infestation reduces by upto 30% because of proper spacing and taking care of plants very closely.

System of Wheat intensification technique has high potential in providing higher yields and ultimately contributing for socio-economic development of the farmers.

Principles of SWI

SWI is mainly based on the following two principles of crop production:

1.Principle of Root Development
Healthy root development is an important factor for healthy growth of a plant. Conventionally, Wheat seeds are sown in a closer manner i.e., no specific space is maintained between the seeds leading to competition between the roots of the plants for nutrients, water and sunlight. The weed population will be higher because of closer spacing, thereby increasing the number of competitors for the resources (Kaur,2012). Root growth inhibition is promoted by crowding leading to poor resistance for the weeds .SWI technology involves proper plant spacing, roots of the plants gets proper space to spread out, better nourishment, better light, more oxygen and the soil quality is also improved by the period of time leading to higher number of effective tillers, higher yields and better nutritive quality.

2.Principle of intensive Care
The plant growth is usually hampered by many biotic and abiotic factors, major factors include improper nutrients and water availability, poor water and nutrients quality, disease incidence, Insects/pests and weeds. Principle of intensive care does not support higher number of plant population per unit area rather it holds up with proper space maintenance and close monitoring and care of the plants. This can be done by adopting Good Agricultural practices, time to time soil and water testing and close monitoring of the plants.

2. Materials and Methods

2.1 Land preparation

Land preparation is an important component of farming. Land preparation was done in two steps:

a. Primary cultivation entails deep penetration of the soil up to a depth of 15cm to 75cm using harrow leaving a rough surface. The aim of this operation is to prepare the land for secondary cultivation.
b. Secondary cultivation was done to pulverize level and firm the top layer 5cm to 15cm of the soil using rotavator. This process aerates the soil, which enables it to gain warmth quicker so plants can grow.

2.2 Seed selection

Seeds of Wheat (Variety- HD-2851) were selected for the study in accordance to the weather and sowing conditions. This is a late sown variety of Wheat.

2.3 Preparation of hydroponics 7- Days Nursery

Hydroponics is technology of growing plants in a liquid nutrient solution with or without the use of artificial media. It is a soil-less method of growing plants.

Ayurvet's Progreen Hydroponics machine is an environmental controlled chamber where crop can be grown irrespective of weather conditions. Multilayer shelves are used for growing Wheat nursery. The amount of light entering in the chamber is controlled by glazed windows. Specially prepared nutrient solution is sprinkled at regular intervals to fulfill all the nutritional requirements. With Ayurvet's Pro green hydroponics machine green, luscious, healthy and highly nutritious Wheat nursery can be grown continuously irrespective of the weather conditions.

Wheat seeds of the variety HD-2851 were washed and soaked overnight. The soaked seeds were then further placed in trays of the hydroponics machine, thereby initiating the 7 days growth cycle.

Basic growth conditions:

Temperature: 18-25 ^{o}C

Humidity: 60-70%

2.4 Sowing of nursery following SWI

The 7 days hydroponically raised Wheat nursery was transplanted in the soil on 8th day and the conventional nursery was sown on 26th day since it takes 25 days for maturity. Date of sowing for all the treatments was same.

2.5 Experimental design

Following SWI proper spacing was maintained between the plants. The experiment was designed using Randomised Block Design (RBD). Following treatments were made which specify different plant to plant spacing. Spacing was maintained using measurement tape, rope and chalk powder. Seedlings were sown at the marks made by chalk powder.

T1- Control (Conventional Method)

T2- Hydroponics 8 Day seedling in field with 10cmX10cm spacing between plants

T3- Hydroponics 8 Day seedling in field with 15cmX15cm spacing between plants

T4- Hydroponics 8 Day seedling in field with 20cmX20cm spacing between plants

DESIGN: RBD

No. of replications-4 **Number of treatments- 4**

Total number of blocks = 4X4= 16 **Size of each plot- 36 Sq ft**

T_1R_1	T_3R_4	T_4R_3	T_2R_4
T_4R_4	T_2R_1	T_1R_2	T_3R_3
T_3R_2	T_1R_3	T_2R_2	T_4R_1
T_2R_3	T_4R_2	T_3R_1	T_1R_4

2.6 Growth conditions and Harvesting

Time to time irrigations was provided to the plants and proper care was taken.

Harvesting was done after maturity i.e., after 4 months of sowing of seedling in the soil. Manual harvesting was done.

2.7 Data recording

Data for following parameters, recorded at desired intervals in order to monitor the performance of the experiment:

a. % Survival of the crop
b. Plant height
c. Effective number of tillers
d. Panicle length
e. Number of grains per panicle
f. 1000 seed weight (gm)
g. Yield per sq m
h. Yield / acre
i. Total biomass/ sqm

2.8 Proximate analysis of grain

a. Protein content
b. Fiber content

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3. Result

3.1 Hydroponics 7 day nursery preparation cycle in Ayurvet's Hydroponics Pro Green Machine

Figure 1- Day 1- Soaked Wheat grains on Hydroponics trays

Figure 2- Day 2- Initiation of sprouting

Figure 3- Day 3- Initial shoots starts appearing

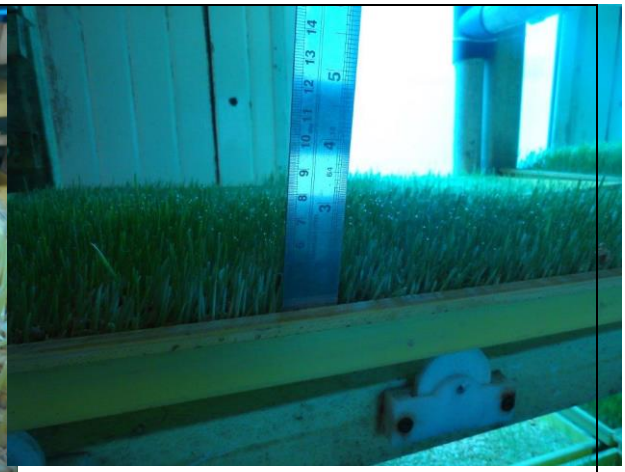

Figure 4- Day4- 0.5-1 inch shoot growth

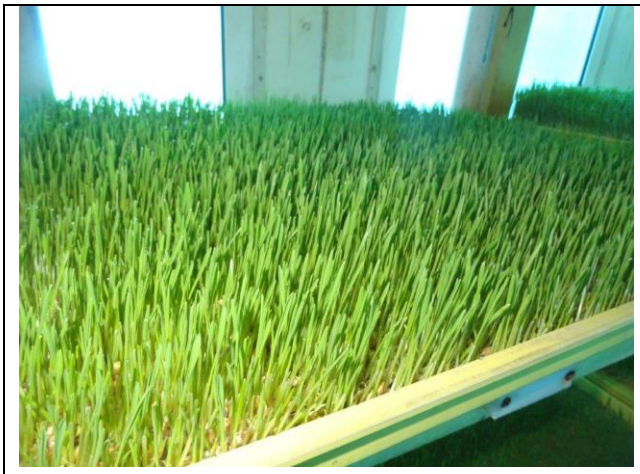

Figure 5- Day 5- 2-3 inch shoot growth

Figure 6- Day 6- 2-3 inch long grass, ready to harvest

Figure 7- Day 7- 5-6 inch long grass, ready to harvest

Figure 8- Day 8- Wheat seedling (6 inches)

3.2 Vegetative stage: The phase of plant growth that occurs between germination and flowering stage is referred to as vegetative stage. Majority of plants foliage is developed during vegetative stage. (*plantsinmotion.bio.indiana.edu*/plantmotion/vegetative/veg.html)

Figure 9- T_1R_1– Conventional Broadcasting Method

Figure 10- T_2R_1- Seed sown with 10cmx10cm spacing

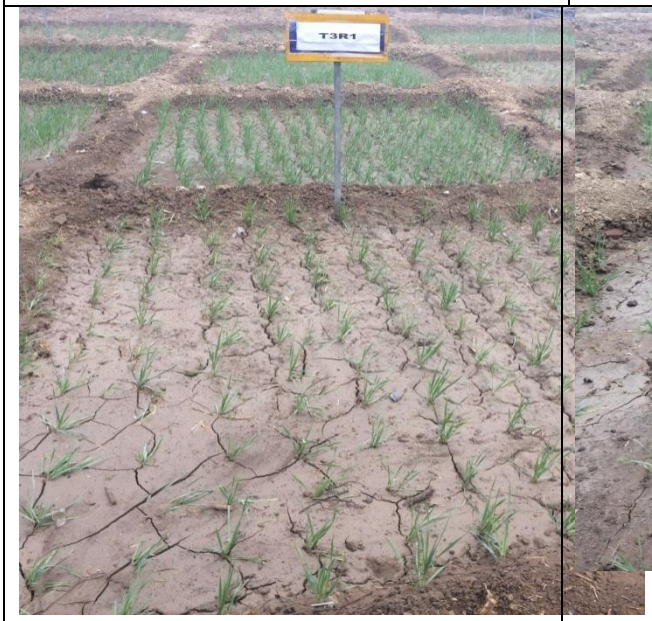

Figure 11- T_3R_1- Seed sown with 15cmX15 cm spacing

Figure 12- T_4R_1- Seed Sown with 20cmX20cm spacing

3.3 Tillering Stage

Tillering basically refers to the stage when plants start to produce its lateral branches (tillers) (orages.oregonstate.edu › Grass Growth and Regrowth for Improved Management)

Figure 13- T_1R_2- Plants grown with broadcasting method

Figure 14- T_2R_1- Plants grown with 10cmX10cm spacing

Figure 15- T_3R_3- Plants grown with 15cmX15cm spacing

Figure 16- T_4R_2- Plants grown with 20cmX20cm spacing

3.4 Flowering Stage

The growth phase where plants starts producing their flower sets, vegetables and fruits is referred to as flowering stage (https://www.maximumyield.com/definition/2570/flowering-stage)

Figure 17- T_1R_3- Broadcasting method

Figure 18- T_2R_3- 10cmX10cm spacing

Figure 19- T_3R_2-15cmX15 cm spacing

Figure 20- T_4R_3- 20cmX20 cm spacing

3.5 Maturity / Harvesting Stage

After ripening and moisture loss the kernels become yellow in color, which indicates that the crop is ready for harvesting. The process of collecting matured Wheat crop from the field is referred to as harvesting stage. It significantly affects the grain yield and quality. (www.knowledgebank.irri.org/postproductioncourse/...harvesting/what-is-harvesting).

Figure 21-T_1R_1- Broadcasting method

Figure 22- T_2R_2- 10cmX10cm spacing

Figure 23-T_3R_4- 15cmX15cm spacing

Figure 24- T_4R_4- 20cmX20 cm spacing

3.6 Panicle length

Panicle is a small cluster of flowers present at the end of a stem. These flowers have the potential to develop into a fruit which further directly produce seed. The panicle length affects the yield of the crops.

Figure 25- Comparison between panicle lengths of T_1 and T_2

Figure 26- Comparison between panicle length of T_1 and T_3

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Figure 27- Comparison between panicle length of T_1 and T_4

4. Observation and Data Recording

Parameter	Conventional (T1)				Hydroponic nursery 10 cm space (T2)				Hydroponic nursery 15 cm space (T3)				Hydroponic nursery 20 cm space (T4)			
	T1R1	T1R2	T1R3	T1R4	T2R1	T2R2	T2R3	T2R4	T3R1	T3R2	T3R3	T3R4	T4R1	T4R2	T4R3	T4R4
No. Of tillers	11	12	12	11	17	14	17	16	15	15	15	16	21	21	21	21
Plant height(cm)	90	76	87	84	78	79	86	88	88	88	88	77	90	89	88	84
Panicle length(cm)	10	10	10	10.4	11.6	11.6	12	10.8	12.2	11.6	12.6	12	11.8	13.2	12	13.4
No. Of grain / panicle	49	47	56	51	51	52	51	54	54	54	51	53	59	57	58	55

1000seed weight (gm)	30.2	31	30.5	30.8	31.9	31.5	31.6	31.4	31.5	31.6	31.8	31.6	32.2	32.6	33.1	32.8
Yield / sq mtr.(kg)	0.45	0.49	0.49	0.49	0.63	0.57	0.49	0.62	0.55	0.53	0.53	0.62	0.43	0.46	0.44	0.49
Yield/ acre (qt.)	18.4	19.8	19.8	20.0	24.6	22.5	20.2	25.0	21.5	21.7	20.8	25.0	16.9	18.1	17.8	17.7
Total biomass/ sq mtr.(kg)	1.12	1.33	1.3	1.55	1.7	1.63	1.15	1.44	1.44	1.22	1.46	1.46	1.43	1.23	1.32	1.15

4.1 Data Analysis using OPSTAT software

Treatment	No. Of Tillers		Plant Height (cm)		Panicle length (cm)		Grain/ Panicle		1000 seed weight (gm)		Yield(kg/acre)		Yield (kg/sqm)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	11.5	0.289	84.25	3.01	10.1	0.1	50.75	1.931	30.625	0.175	1,956.48	36.441	0.484	0.009
2	16	0.707	82.75	2.496	11.5	0.252	52	0.707	31.6	0.108	2,311.10	111.631	0.582	0.03
3	15.25	0.25	85.25	2.75	12.1	0.208	53	0.707	31.625	0.063	2,229.30	94.726	0.562	0.02
4	21	0	87.75	1.315	12.6	0.408	57.25	0.854	32.675	0.189	1,766.25	25.643	0.46	0.014
C.D.	1.385		N/A		0.972		4.223		0.48		222.03		0.053	
SE(m)	0.427		2.569		0.3		1.302		0.148		68.438		0.016	

*Treatments found significant at 5% level of significance

Discussion

T1- Control (Conventional Method)

T2- Hydroponics 8 Day seedling in field with 10cmX10cm spacing between plants

T3- Hydroponics 8 Day seedling in field with 15cmX15cm spacing between plants

T4- Hydroponics 8 Day seedling in field with 20cmX20cm spacing between plants

Plant height is usually same in all the treatments but the numbers of tillers were significantly better in Treatment 2, 3, & 4 when compared with Treatment 1 (control- broadcasting method). Highest numbers of tillers were recorded in hydroponically raised 8 days Wheat seedling transplanted with 20cmX20cm spacing i.e., Treatment 4 and minimum was recorded in Treatment 1 broadcasting method. Highest number of tillers in Treatment 4 can be explained by the fact that proper spacing facilitates lower plant population, lower weed population, thereby relatively poor competition between the roots of the plants and weeds for resources like light, nutrient and water.

The panicle length of all the 3 Treatments were significantly better than the Treatment 1. The recoded maximum and minimum length of the panicle was 13cm in Treatment 4 and 10 in Treatment 1, respectively.

Significantly higher grain yield was observed in Treatment 2 & 3 which can be because of wider spacing, proper aeration, plant population, intensive care and the use of Hydroponics transplants. Significantly higher 1000 seed weight was recorded in all the three treatments (T_2, T_3 & T_4) .Highest 1000 seed weight was recorded in Treatment 4 and lowest was recorded in Treatment 1. Chopra and Sen. (2013) has also reported similar grain yield in comparison with broadcasting method. Kumar and Raj (2014) also recorded significantly higher grain yield in 10cmX10cm spacing as compared to 15cmX15cm and 20cmX20cm spacing.

According to present investigation, there was no significant difference between Treatment 2 and Treatment 3 for almost all the parameters under study though they were significantly better than the Treatment 1 which is broadcasting method. Non-significant difference between treatment 2and 3 depicts that the difference of 5cm in sowing space is not showing much effect on the parameters under study whereas ,the sowing of Hydroponically raised Wheat seedling with 20cmX20cm spacing showed significant increase in all the parameters except for yield. Reduced yield can be because of lower plant population.

4.2 Protein, Fiber and Moisture analysis

S.No.	Parameters	T1	T2	T3	T4
1.	Crude Protein (%)	13.35	12.98	13.66	13.67
2.	Crude Fiber (%)	2.22	1.96	2.08	2.72
3.	Moisture (%)	8.55	8.28	8.27	8.14

The results obtained indicate that the highest percentage of crude protein content was found in T4 followed by T3, T1 and T2, respectively. Whereas the highest fiber content was recorded in T4 and the lowest was found in T2.

5. Summary & Conclusion

Food security is increasing day by day whereas food production is not sufficient or decreasing due to various factors .Wheat is the second highest produced crop in India after Rice, still the Wheat growing farmers are not very happy with their produce and often faces losses.

One of the major reasons of the losses faced by the farmers is the local traditional practices followed by the farmers; we need to prompt farmers to adopt new practices in order to get better returns with lower input cost.

In view of the same an experiment was conducted at Ayurvet Research Foundation, Chidana. Wheat nursery was raised hydroponically and transplanted in soil following SWI technique. SWI is not very renowned technique and is based on the principle of System of Rice intensification. Through SWI fixed distance/space is maintained between two consecutive sown seeds. The spacing varies from 10cm-20cm. The spacing facilitates proper root development leading to better performance. An analysis of the results of this experiment had shown

superior performance of hydroponically raised 8-day seedling, transplanted in soil following SWI with 10cmX10cm spacing in all vegetative and yield parameters under study. The second best performance was recorded in15cmX15cm spacing followed by conventional broadcasting method and 20cmX20cm spacing. The poor result of 20cmX20cm SWI spacing can be because of lower plant population also the experimental area per treatment was very small. Results indicate direct yield gain of 18% (2311.1 kg/acre) and 13% (2229.3 kg/Acre) in 10cmX10cm spacing and 20cmX20cm SWI spacing respectively when compared with conventional broadcasting method (1956.4kg/Acre). This is an efficient technique whose activity does not alter under unfavourable conditions (stress conditions).

The highest crude protein and crude fiber content was recorded in SWI-20X20cm spacing followed by SWI 15X15cm spacing, conventional and 10X10cm spacing. The seedlings sown with 15cmX15cm spacing had got proper aeration, proper nutrition facilitating better root growth and high percentage of nutrient accumulation. However the highest grain yield was obtained in 10X10cm spacing which can be because of higher plant population.

This experimental trial had provided strength to the technology on scientific basis providing analyzed statistical data in terms of various growth and yield parameters under study. However, more detailed study is needed on various biophysical changes in the plants under SWI method and the experiment needs to be conducted on larger scale for authentication.

This technology is very popular amongst the farmers of Bihar, Madhya Pradesh, Rajasthan, Chhattisgarh and Uttarakhand but the farmers of Haryana are still not aware of SWI technology. In view of same, more skill oriented training and demonstration programs needs to be conducted for the farmers of Haryana for better acceptance and socio economic upliftment of the farmers.

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A Brief Author Biography

Abha Saxena – Abha Saxena holds a Master's degree in Biotechnology from Banasthali Vidhyapith, Rajasthan .She currently works at Ayurvet Research foundation , New Delhi as Trainee- Research and Development. She has an excellent scientific acumen and is meticulous. She holds experience with field research integrity and is familiar with all laboratory equipments and materials. Her time management and organizational skills are commendable. She nurtures a keen interest in developing farmer's friendly techniques which can help them grow and attain sustenance.

Tarun Upadhyay, Research Scientist was born in July'1984 in Uttar Pradesh. His basic areas of interest includes Soilless gardening, Home hydroponics for producing leafy vegetables ,Home made fertilizer through kitchen waste. Did his undergrad degree in Zoology, Botany and Chemistry from Rohilkhand University, Bareilly. A Techno-commercial person with 10 years of diverse experience in interdisciplinary Quality Assurance/Quality Control in Ayurvedic Product Formulation, Operation Research Project of Soilless Techniques for producing green fodder for Animals and Nurseries of Crops . Presently serving Ayurvet Research Foundation as Executive-Research. A self-motivated professional with keen analytical abilities & in depth understanding of the economics and dynamics of Agriculture .

Dr. Deepti Rai, A Techno-commercial person with 15years of diverse experience in interdisciplinary Research & Development. Qualified Ph.D(Horticulture) from GB Pant University & Agriculture and Technology , Presently serving Ayurvet Research Foundation, Delhi as Manager-Research & Projects. A self-motivated professional with keen analytical abilities & in depth understanding of the economics and dynamics of Agriculture & Biotechonolgy. In nutshell, I am a Scientist with Business Acumen.

