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Review on SYI (Sustainable Yield Index) of Wheat (*Triticum aestivum* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Wheat is the major cereal and staple food crop of most of the northern regions of the country. Productivity of wheat in India is very low compared to other major producer countries of the world such as France (72542 Hg/ha), China (50505 Hg/ha) but sustainable yield index (0.832) is more compared to the China (0.800) and Russia (0.738) which indicate that there is no significant increment in the productivity of wheat and stagnation in the yield of wheat in India over a period of time. However, by identifying sub-optimal conditions an efficient scientific management can improve the wheat yield potential of the country to meet the future demand of food grain for increasing population.

Keywords: Wheat; SYI; productivity.

1. INTRODUCTION

Wheat is the most important cereal crop of India after rice and is a staple food of most of the Indians particularly in the northern and north-western parts of the country. It is rich in carbohydrates and it's protein content is double than rice, hence it provides balance food.

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Although India has first rank in area under wheat but it has second place in production in the world standing next to China and accounts for 13 per cent of the world's total production.

1.1 Conditions for Growth

In India Wheat is a winter season cropwhich requires cool temperature the during initial growth stages and is harvested in the beginning of summer.

Wheat is a photoperiod sensitive crop, hence its production potential is very much affected by the length of photoperiod during growing season. If there is more the length of photoperiod there would be more yield per unit area or vice versa. Longer photoperiod leads to more light energy input and longer time of photosynthesis, so that longer photoperiod provided more photosynthate and increased seed yield [1].

Ideal climate for wheat cultivation has winter temperature of 10º to 15ºC and summer temperature varying from 21ºC to 26ºC. The temperature should be low at the time of sowing but when the crop approaches towards the time of harvest higher temperatures are required for proper ripening. It is mostly grown in irrigated conditions and it can also be grown in the areas receiving an annual rainfall of 7500 mm. About 5 to 7 irrigations are required in irrigated areas depending upon the amount of rainfall. Although wheat can be grown in a variety of soils, well drained fertile, friable loams and clay loams are the best suited soils for wheat cultivation [2].

1.2 Production

Leading wheat producing states in country are Utter Pradesh followed by Punjab Fig. (1).

2. SYSTINAIBILITY YIELD INDEX

2.1 Sustainable Yield Index (SYI)

The yield data from different centers was processed and interpreted in terms of SYI. The SYI of individual crops at different locations of LTFE experiments was calculated following the equation suggested by Singh et al. [4].

$$SYI = (Yt - \sigma) / Ym$$

Where Yt is mean yield of respective treatment, σ is the standard deviation (SD) and Ym is the

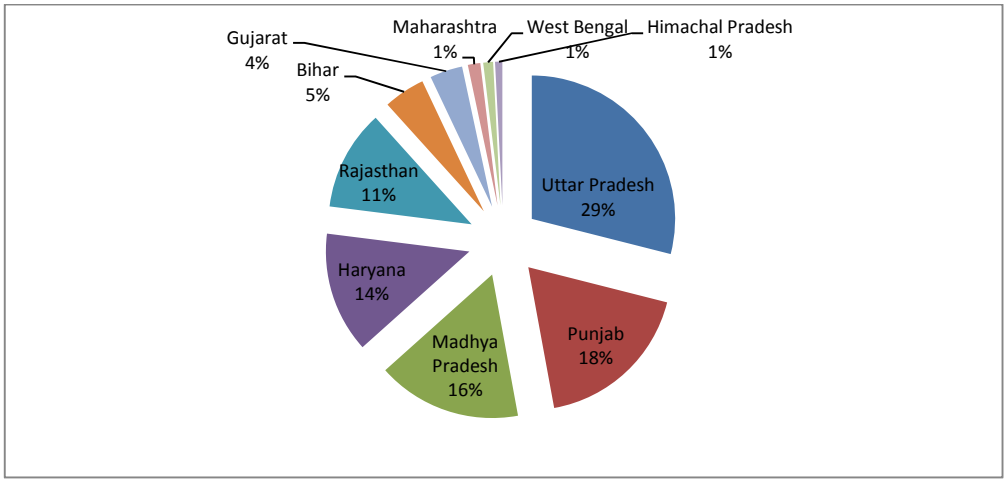

Fig. 1. Top ten wheat producing states of the India (2014-2015)

Table 1. Sowing time of wheat in India under different climatic zones

States	Sowing time	Harvesting time
Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh and West Bengal	September-October	Jan.- Feb.
Bihar, Uttar Pradesh, Punjab, Haryana and Rajasthan	October-November	March-April
Himachal Pradesh and Jammu & Kashmir	Nov.-Dee.	April-May

Table 2. Top 10 Wheat producing states of the India (2014-2015)

State/ UT	Wheat (Th. tonnes)	Production (Th. tonnes)
P	Uttar Pradesh	25220
2	Punjab	15783
3	Madhya Pradesh	14182
4	Haryana	11856
5	Rajasthan	9869
6	Bihar	4049
7	Gujarat	3220
8	Maharashtra	1236
9	West Bengal	950
10	Himachal Pradesh	721

Sources: Directorate of Economics and Statistics, Ministry of Agriculture (2014-2015) [3]

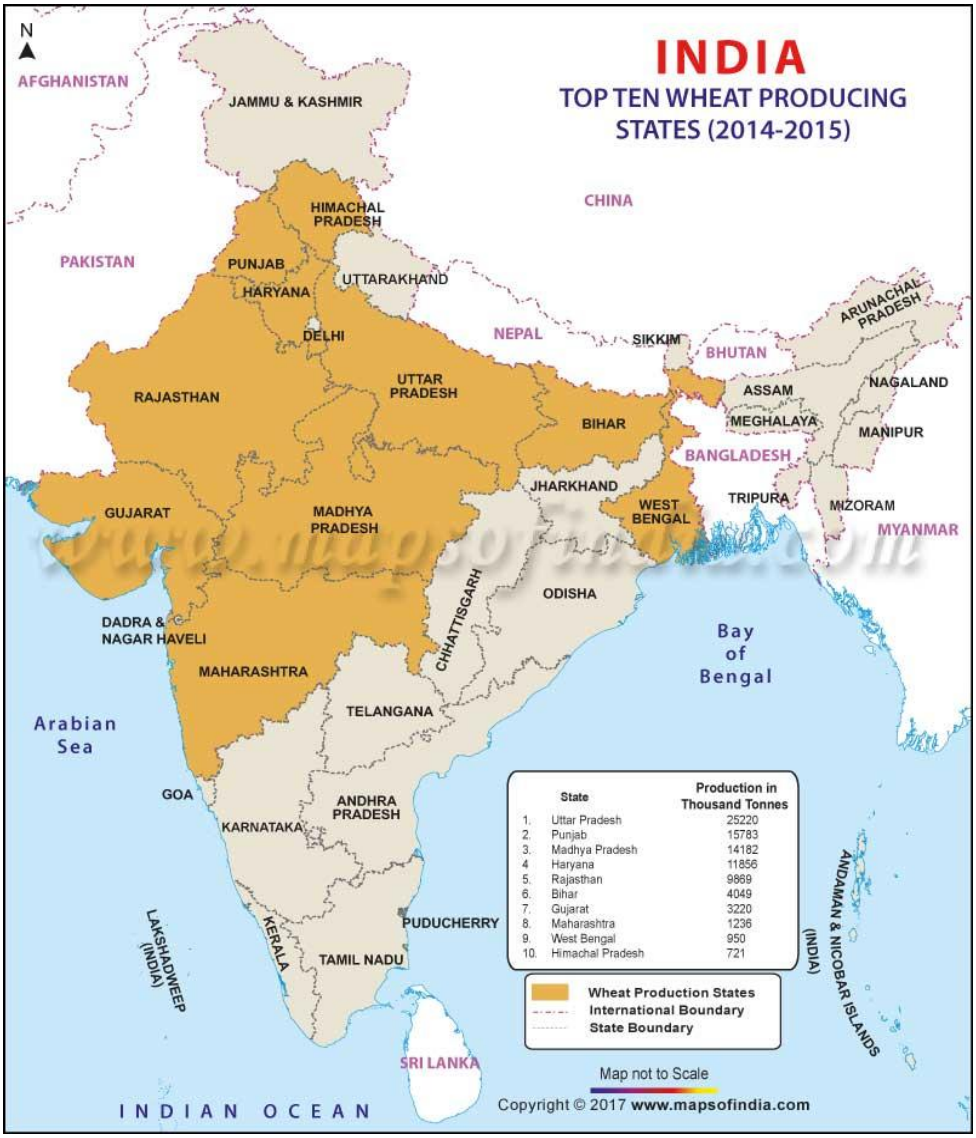

Fig. 2. Top ten wheat producing states of the India (2014-2015)

Sources: Directorate of Economics and Statistics, Ministry of Agriculture (2014-2015) [3]

maximum yield obtained under a set of management practices in any of the treatment and any of year in a given experiment Singh et al. [4]. It indicates that sustainability in production over a period of time even though crop has high yield may or may not give sustainable yield index. Sustainability depends upon variation in the yield during crop period like if during the initial period yield is very low and after 8-9 years it reached very high, as here variation is more from starting period to last there is more yield but less sustainability and if crop yield variation is less from the beginning to the end there may be higher or lower yield but SYI would be higher.

Among the top wheat producing countries of the world the sustainable yield index is highest of the France followed by USA, India, China and lowest for Russia which indicates that even productivity of the France is highest but the fluctuation in the yield from 1992 to 2013 was less asthere is no much increment in the productivity of France during this period. Hence, achieved more SYI. However, wheat productivity of China is more than the India but SYI is less compared to India which revealed that the productivity of China increased rapidly from 1992 (33.3 q/ha) to 2013 (50.5 q/ha) which result in more fluctuation in the productivity which result in low SYI of China.

2.2 Why France and USA have High Wheat SYI

Wheat productivity of France is highest because following favorable conditions for wheat

Table 3. Productivity of wheat in top five wheat country of world since 1992 to 2013

Country	France	China	USA	India	Russia
Year			Yield (Hg/Ha)		
2013	72542	50505	31720	31538	22288
2012	75992	49867	31154	31775	17727
2011	61788	48374	29418	29886	22645
2010	64419	47484	31167	28395	19181
2009	74469	47390	29897	29071	23182
2008	71018	47620	30175	28022	24459
2007	62542	46076	27046	27079	21007
2006	67414	47238	25986	26188	19492
2005	69887	42753	28231	26016	19324
2004	75787	42519	29026	27132	19814
2003	62499	39318	29712	26100	17047
2002	74454	37766	23567	27621	20676
2001	66170	38061	27018	27081	20577
2000	71171	37382	28238	27785	16141
1999	72431	39466	28726	25901	15690
1998	76058	36852	29034	24852	13602
1997	66237	41019	29034	26789	18427
1996	71323	37341	24389	24828	15487
1995	65079	35415	24065	25590	13946
1994	66681	34263	25270	23796	14498
1993	64722	35188	25699	23267	17655
1992	64042	33312	26433	23940	19030

Note: 1000 hectogram (hg)/ha= 1.0 quintal/ha
Sources: www.fao.org/statistics/faostat agriculture. [5]

Table 4. Sustainable yield index of wheat in top wheat growing country of world

Country	France	China	USA	India	Russia
Mean	68942	41600.4	27954.8	26938.7	18722.5
Yield max	76058	50505	31720	31775	24459
SD	1045.88	1213.68	522.029	499.264	663.346
SYI	0.893	0.800	0.865	0.832	0.738

Sources: www.fao.org/statistics/faostat agriculture [5]

cultivation in wheat growing regions. In France yields were higher than other producers in 1966 and continued to climb at higher rates from 32.6 q/ha to 74.9 q/ha. The climate of France varies from oceanic to continental, with very cold and usually wet winters and wheat grown is mostly winter-habit type and is sown in the autumn (September and October) and harvest occurs in July and August which indicates length of photoperiod is more which result in more yield per unit area CIMMYT report (1999) [6]. Use of CCC reduce the plant growth and prevent from lodging and produce more grain yield of wheat because lodging affects the grain filling and size, weight of the grain. In France wheat growing area (west of the Alps, stretching across France to the english channel and up to the North Sea) is naturally very productive which is enabling to produce more yield per unit area of wheat in France. (http://www.earthpolicy.org/mobile/books/fpep/fpepch7) [7]. Similarly other reasons are highly flexible rotations (Sugar beets/wheat/barley or corn/wheat/barley crop rotation dominant) and strong seed organizations, wheat breeding is done primarily by private sector, higher fertilizers use, higher pesticides use also resulted more productivity of wheat in France.

United States wheat production is very chemical-intensive and according to the U.S.D.A report2013 [8], wheat producers apply more than 7.3 million Kg of pesticides to the fields every year, at average rates ranging from 1 to 3 Kg per hectare. About half of winter wheat fields in the United States are sprayed with herbicides, while some 95% of fields of spring and durum wheat varieties are sprayed. Hence, long duration winter wheat and chemical intensive cultivation resulted more yield in USA also due to favorable climates and effectively management of pest and disease by using chemicals reduce the yield losses and produce more yield per unit area.Wheat production account more than 85% nitrogen applied as synthetic fertilizer forms and high mechanized cultivation: more machinery is used per ton of production for wheat.

In the United States, mostof the wheat grows in the semiarid Great Plains, whereas in France it is produced on the well-watered, rainfed wheat fields. Hence, average wheat yield of United States is lower than France [7]. However, since 1992 to 2013 there is no much variation in wheat cultivation practices and inputs used in wheat cultivation, like using high yielding variety of winter wheat, long photoperiod are responsible for sustainability in wheat productivity USDA, Economic Information Bulletin Number 116 [8].

2.3 Why the Wheat Productivity in China is more than India

SYI of China indicating rapidly increment in the yield of the crop during the period of estimations, which result from favorable condition and efficient crop management practices used for wheat production. In China, combining winter wheat with corn as the summer crop in an annual cycle, plus the double cropping of rice, enables the country to produce the world's largest grain harvest on a relatively modest area of arable land. In China wheat is grown on irrigated (80-85%) land, mechanization and fertilizer use in china much higher than the India which resulted in more wheat yield in China which is 40 to 60% higher than the Indian wheat yield. The adoption of modern varieties and the increased use of irrigation and fertilizers during Green Revolution dramatically increased crop yields all over the world [9]. Similarly other reasons for more yield in China compared to India such as China invests significantly more in agricultural research and development compared to India to produce high-yield. This along with better irrigation and more intensive cultivation of the land by double or even triple cropping are the primary reasons for China's superior yields. The general nitrogen recommendation for wheat in India 150 kg/ha and sometimes the temperature is very high during flowering stages of wheat which severely affect the wheat grain filling, grain formation and phtotosynthates accumulation, DARE//*ICAR* ANNUAL REPORT 2013–14 [10] but in China based on farmer practices general nitrogen recommendation 250 kg/ha and average temperature in most of wheat growing regions low (below 15ºc) which provide favorable condition for high photosynthates accumulation and result in more yield Tobias et al. [11]. In China The cropping season for winter wheat ranges from about 180 days for early ripening wheat (in the Sichuan area) to 280 days for late ripening wheat (in northern China). Alluvial and loessial soils predominate in regions of greatest wheat production these favorable conditions promote more production of wheat in China Gary M. Paulsen [12].

Wheat (*Triticum aestivum* and *T. durum*) is the most important cereal crop of India mostly grown as winter cereal during 15 October to mid-April. India divided into six major wheat growing zones, based, soil types and growing period on and

other general requirements. The Indo-Gangetic plain comprising the North Western Plains Zone (NWPZ) and the North Eastern Plains Zone (NEPZ), are the major wheat growing tract followed by the Central Zone (CZ) and the Peninsular Zone (PZ). The Northern Hill Zone is still dominated by traditional cereal growing with varieties that mature in May/June, while the Southern Hill Zone has a mini scale area of few hundred hectares under the tropical cold humid environment.

The average wheat productivity of India is very low compared to other top four leading countries mainly due to successive sub-normal monsoon precipitation, area under rainfed wheat in CZ (Central zone) and PZ (Peninsular Zone) reduced and consequently average wheat productivity and total wheat production also reduced. These sub-normal climate and weather conditions shows the vulnerability of our wheat production and the risk to food security. Similarly fertilizer consumption in India is low compared to other countries for wheat productions. Nagarajan [13] Fertilizer consumption pattern of UP was examined in great detail for N, P and K and recorded a marginal increase in N consumption during the last decade. But, like Punjab, in UP districts also, application of P and K declined over time and it was also reported that annual fertilizer consumption in Punjab, Haryana and Uttar Pradesh from 1990–91 to 2002–03, supplied by the Indian Agricultural Statistics Research Institute, New Delhi, showed that since 2000 there is stagnation in the application of nutrients as N, P and K.

Due to continuous application of narrow band of fertilizers and almost total withdrawal of organic manures (FYM, Compost, Vermin compost) or green manuring practices have created widespread micronutrient deficiency which leads to reduce in the yield of the crop over a period of time because according to the Liebig'slaw of minimum deficiency of one nutrient limit the crop yield even if all other nutrients are adequately supplied.

Rajendra Prasad [14] reported that sulphur in our soils reduced the factor of productivity and is causing yield depression and poor profit margin. This inadequate nutrient management, lack of irrigation, high temperature during grain filling, low length of growing period, less chemically intensive, less mechanized compared to other top producing countries and sub normal

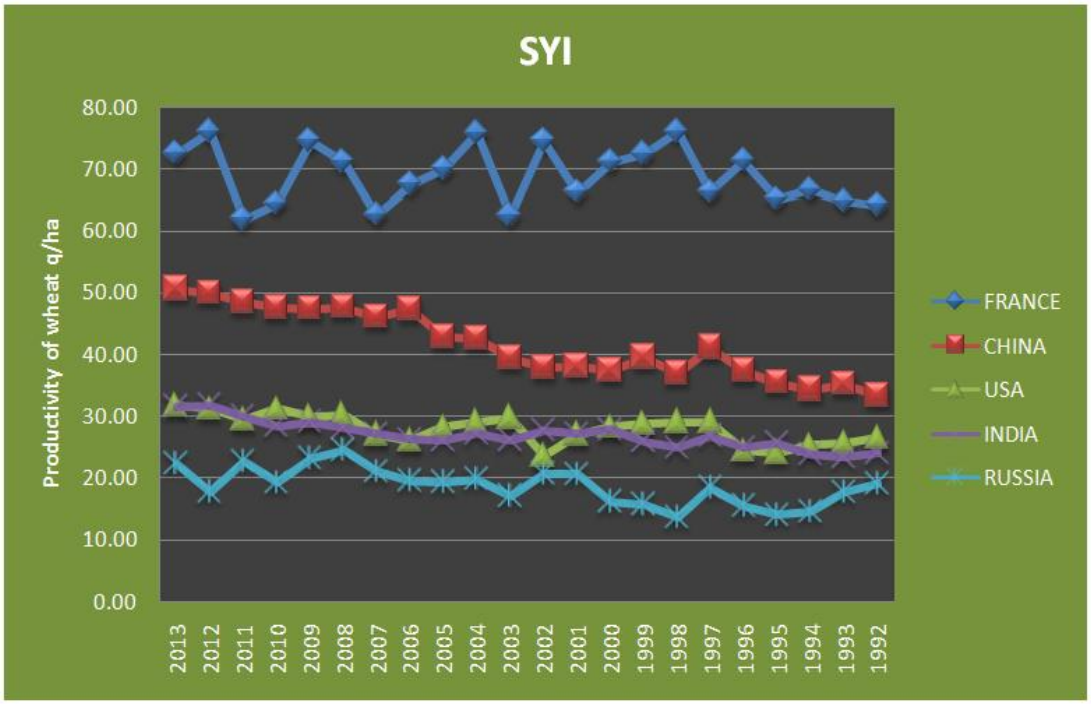

Fig. 3. Sustainable yield index of wheat in top wheat growing country of world

monsoon and weather conditions during flowering are the main reasons for low productivity of wheat in India. An examination of the yield performance of the advanced material in the All India Coordinated Wheat Improvement Project (AICWIP) multi-location yield trials of the timely sown conditions of NWPZ, shows that during the last decade there was no entry that yielded statistically higher than PBW343. In other words, the 1% annual genetic gain in yield achieved by wheat varietal breeding resulted in low productivity of wheat in the country [15].

In India due to climate vulnerability and low consumption of fertilizers there is no drastically increment in wheat productivity like China so yield of wheat is sustain and recorded higher SYI compared to China but china obtained low SYI dueto more fluctuation in yield mainly because initially wheat productivity in china was low but present due to mechanization and using high chemicals in wheat production resulted significantly increased wheat productivity due to this variation over the period in yield responsible for low SYI of china.

2.4 How the Wheat Productivity in India can be increased

From the above discussion the following points emerge as limitations in increasing wheat productivity but by addressing them, there can be a sustained increase in the productivity of the wheat in the country.

1) Balanced use of nutrients in Punjab and in the Indo-Gangetic plain (NWPZ + NEPZ) where micronutrient deficiencies has been reported and enabling policy environment to use of efficient nutrient management toolsto achieve sustainable higher yield.
2) Use of customized or complex fertilizers to prevent from specific nutrient deficiencies and provide all nutrients to the crop to achieve full yield potential of the crops. It will also help to reduction in the factor of productivity is due to 'law of minimum'.
3) Designing the new fertilizer policy to promote addition of micronutrients or produce fortified fertilizers to provide balance nutrients to the crop.
4) Therefore, the pricing of wheat has to be examined and it should be used as an instrument to increase production as well as grain quality [13].
5) Timely control of weeds before onset of the competition for healthy growth of crop plant which helps to achieve full genetic yield potential crop because crop plant will get adequate growth resources in absence of competition.
6) Improve the genetic potential of the crop by genetic engineering and bio technological approach to achieve higher yield potential under water, heat stress and improve sink sources capacity of the plant.
7) Development of C_4 wheat by use of breeding, genetic engineering and biotechnological methods by selection or transfer of gene from C_4 wild spp to wheat to achieve higher productivity under climate change conditions.
8) Development of photoperiod insensitive wheat cultivars which will produce more yield even under high temperatures during flowering resulting in more response of the crop to available growth resources.
9) Increase photosynthetic efficiency and reduce the transpiration losses of water from the plants.
10) A critical assessment of the factors affecting and reasons for wheat yield stagnation at zonal and micro-level action plan focusing on wheat yield stagnated areas develop policy and technology to increase the yield potential in these areas.
11) Improve mechanization to prevent yield losses.

3. CONCLUSION

Sustainability yield index indicates that sustainability in production over a period of time even though crop has high yield may or may not give sustainable yield index. Sustainability dependsupon variation in the yield during crop period like if during the initial period yield is very low and after 8-9 years it reached very high, as here variation is more from starting period to last there is more yield but less sustainability and if crop yield variation is less from the beginning to the end there may be higher or lower yield but SYI would be higher. Among the top five wheat producing countries of the world, France recorded highest SYI followed by USA and India. However, lowest SYI recorded in case of China over the period of 1992 to 2013.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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