

RESEARCH ARTICLE

Effective approaches for sustainable wheat production under changing global perspectives-A reappraisal

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ABSTRACT

Attaining food security had been a major challenge for the nation since independence. Stagnant wheat production growth rates, depletion of grain stocks due to production shocks coupled with increasing demand for food has contributed to dwindling supplies. As a result, physical, economic and ecological access to wheat still remains our major challenge. In this paper author try to highlight current problem in wheat cultivation and how to mitigate with some aspect, for betterment of wheat share in Indian economy. Further, an experiment was conducted at District Seed Farm (AB Block), Kalyani under Bidhan Chandra KrishiViswavidyalaya during winter season of 2014-16, with the objective to mitigate temperature problem (by manipulating sowing date i.e. 10th November, 25th November, 10th December and 25th December) with suitable cultivars (i.e. DBW 107, HD 2967, K0307 and DBW 39). , to combat the problem of late harvesting of rice. Good yield and better B:C ratio observed with early sowing with cultivar of K0307 and HD 2967. Suitable crop cultivar with optimum time of sowing, mitigate some extent to alteration of climate problem. Various observations revealed that, barring Haryana, Punjab and Rajasthan, productivity in rest of the states were below the national level. Expecting the impediments for wheat production in the coming years such as climate change, dynamics of pests and diseases, deteriorating soil nutrients, increasing cost of cultivation, global price volatility and changing consumption pattern, researchers have to put tremendous effort to sustain the existing growth trend by developing and sustaining the HYVs having tolerance to biotic and abiotic stresses with improved crop husbandry practices (irrigation, weed, nutrient management etc.). Potential improvements in wheat adaptation for climate change may include breeding new cultivars and changing agronomic practices. So, there is an urgent need to make detail probe on all these relevant issues through empirical research. However, a major role has to be played by the extension personnel in disseminating those improved genotypes through FLDs at farmers' field and try to bridge the existing yield gaps to meet our mission on ensuring food and nutritional security to all population.

Keywords: Constraints, extension approaches, farmers, wheat, yield.

INTRODUCTION

World agriculture has been facing a daunting task of producing sufficient food to meet its growing demand posed by population growth diet preferences, climatic vulnerability, farmland degradation and growing competition for water and energy. Technology did increase the food grains productivity in India till 1990s, but the subsequent growth rate started to decline (Sendhil *et al.*, 2012). There is an increasing evidence of stagnation in crop yield potential world over, and that average crop yields in

major cereal-producing countries have struck a plateau and wheat in particular. India is predominantly an agrarian country where 70 per cent of the population is directly or indirectly involved in agriculture and allied sectors. It is important to recognize that for farmers, maximizing yield is not their sole objective; profitability and managing risk are more important criteria. Agriculture stands on the very complex interaction between biological, climatic and geographical factors in addition to human activities. The information under such a complicated system is unpredictable, unstable, subjective, site specific

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and reliant on empirical decision given the inherent variability of biological phenomena. Under these circumstances our cereal production is stagnant and wheat become in particular. Delivering increased yields is a complex challenge that is unlikely to be solved by a single approach. There are three specific major challenges: increasing yield potential of wheat (the maximum yield for a given genotype under optimal conditions), protecting yield potential, and increasing resource use efficiency to ensure sustainability (Mukherjee, 2014). People depend on agriculture for their livelihood. Wheat is the second most important crop in India and a principal source of calorie intake (Singh *et al.*, 2003). It has been under cultivation in the Indian subcontinent from pre-historic times and is an integral part of the country's economy and food security (Mukherjee, 2015). The country achieved rapid strides in wheat production during the last four decades resulting in self-sufficiency and surplus production. This has enabled the country to meet domestic demand from its own production and reduce dependence on wheat imports. However under changing situation wheat production become threat to our nation due to imposition of various pest, disease and agronomic constraints. Under these circumstances, present paper give glimpse of idea about few important aspects, which directly or indirectly influence wheat production of our state and India as a whole. Our objective is how to sustain wheat production and secure good yield for future food basket.

MATERIALS AND METHODS

The study was primarily based on the survey and secondary data published from various authentic sources and records. Data on area, production and productivity were collected from portals of indiastat and other authentic net sources. Performance of Indian wheat production in terms of growth and instability was examined in the present study. The authors' brief down the holistic view how to improve wheat cultivation by pointing out some typical constraints which face by farming community. Further, an experiment was conducted at District Seed Farm (AB Block), Kalyani under Bidhan Chandra KrishiViswavidyalaya during winter season of 2014-16, with the objective to mitigate temperature problem (by manipulating sowing date) with suitable cultivars, to combat the

problem of late harvesting of rice. The experimental work was conducted in split-plot design with three replications. Four different sowing dates and its impact on four different wheat cultivars were evaluated. The gross size of the plots was 2.07 m x 8 m or 16.56 sq. m (9 rows at 23 cm spacing). The crop was uniformly fertilized with 150 kg N, 60 kg P₂O₅ and 40 kg K₂O per hectare. Optimum agronomic package follow as per need.

RESULTS AND DISCUSSION

Wheat, the cold tolerant crop is cultivated in *Rabi* season. The crop is sown during 2nd fortnight of October to 1st week of January and harvested during the months of March to May across diverse agro-ecosystems. India currently occupies second position in wheat production next to China and the position continues for more than a decade (FAO trade statistics). In 1978, for the first time in the post-independence period, India emerged as a net exporter of wheat (Chand, 2001). However, feeding burgeoning population through the next 25 years remains an uphill task. Increasing domestic and international demand owing to population growth should meet the future challenges of food and nutritional security. Wheat is the most important cereal crop in the World and stands next to rice in India. The share of wheat to total food grain production in India is around 37% and occupies about 24% of the total area under food grains (Table 1). Wheat is grown in India over an area of about 29 million hectares (M ha). Nearly 82-85% of the wheat grown in India is under irrigated conditions while the rest is grown under rain-fed ecology. Nearly 90% of the wheat growing area is in the North Western Plain Zone (NWPZ), North Eastern Plain Zone (NEPZ) and Central Zone (CZ). At the current production level, NWPZ alone produces over 50% of the total wheat followed by NEPZ (less than half of NWPZ) and Central zone. The average productivity of wheat in the country is 2839 kg ha⁻¹ with the highest yield recorded in Punjab (4307 kg ha⁻¹) followed by Haryana (4213 kg ha⁻¹), Rajasthan (3133 kg ha⁻¹), Uttar Pradesh (2846 kg ha⁻¹), West Bengal (2680 kg ha⁻¹) and Bihar (2084 kg ha⁻¹) indicating wide yield differences between the major wheat growing states of the country. The country will have to feed about

1.30 billion people by 2020 requiring 5-6 million tons (henceforth 'mt') of additional food grains every year. India by 2030, will require approximately 100 million tons of wheat to cover an estimated demand of 345 million tons of foodgrains (Sendhil *et al.*, 2012).). The country as per the national policy on agriculture has set a target of 4 per cent growth rate for which high growth in wheat production becomes a mandate owing to its importance in food basket. The growth rate can be achieved by increasing the production and bridging the existing yield gap. Wheat is a staple crop in many countries and hence its consumption is directly proportional to the population growth. Consumption of wheat in rural India has increased apparently due to the availability of nutritious cereal. The share of wheat in total cereals consumption has increased from 25.43 per cent (3.88 kg month⁻¹) in 1972-73 to 37.36 per cent (4.26 kg month⁻¹) in 2016-17 (rural India) while a marginal increase from 45.33 per cent (4.34 kg month⁻¹) to 41.89 per cent (3.92 kg month⁻¹) was observed in urban India. The difference in consumption pattern could be the result of sustainable production and consumption in rural areas, rural-urban price divergence, varied preferences due to higher incomes in the urban areas, and variety of foods available in urban markets (Nasurudeen *et al.*, 2006). Expansion of the area sown to wheat has long ceased to be a major source of increased wheat output and most of the increase in production has to result from greater yield per hectare. As we look at further opportunities to improve production, it becomes evident that there still exist substantial yield gaps within wheat growing regions of the country, as well as between on-station and on-farm yields. Inappropriate nutrient management, poor resource conserving technology, weed management etc. are one of the major factors causing such yield gaps

Question in rice-wheat system

Wheat play crucial role under rice –wheat system throughout in South East Asia and in India particular. This cropping system has been practiced for several decades and the contrasting edaphic needs of these two crops have resulted in increased pest pressure, nutrient mining, inappropriate use and management of

chemical fertilizers, input use efficiency is low and soil organic matter content has reduced (Mukherjee, 2012). In many areas, yields have stagnated at below potential level. In the mechanized rice–wheat cropping system of north-west India, rice residues are normally burnt prior to sowing the following wheat crop. In Punjab State, approximately 16 Mt of rice straw are currently burnt each year by farmers (Singh *et al.*, 2008) and this is a major source of air pollution. To avoid the need to burn the rice residues, a sowing combine, the Happy Seeder (Sidhu *et al.*, 2008), which enables direct drilling of wheat with full rice residue retention, was developed. The Happy Seeder simultaneously chops the straw, sows the seed, and spreads the residues on the soil surface as mulch behind the sowing tynes. Experimental evidence (Singh *et al.*, 2011; Sidhu *et al.*, 2008; Singh *et al.*, 2008) and anecdotal evidence from farmer field trials in the region have shown that the presence of rice mulch maintains or increases wheat yields, and that soil moisture content is higher in mulched wheat. Erratic rainfall, decline in water table, poor soil health, changing pest scenario, lack of innovative technologies are some of the important reasons for yield stagnation. Conservation agriculture (CA) is one of the most prospective approaches for sustainable wheat production. CA is an integrated approach to crop, soil and water management to achieve sustainable agriculture goals. It seeks to conserve, improve and make more efficient use of natural resources through integrated management of soil, water, crops and other biological resources in combination with selected external inputs. It has the potential to address increasing concerns of serious and widespread problems of natural resource degradation and environmental pollution, while enhancing system productivity (Yadav, 2012).

Biofortification

Biofortification is a good approach for quality wheat production, and become more appropriate in the context of tribal and malnourished people. . Zinc (Zn) and iron (Fe) deficiencies are well-documented public health issue affecting nearly half of the world population especially in developing countries like India. Zinc and Fe

deficiencies are the common micronutrient deficiencies in light textured soils of North Gujarat limiting both crop production and nutritional quality. Further, very low concentrations and poor bioavailability of Zn and Fe in the commonly used cereals aggravated the micronutrient deficiencies. Breeding new wheat genotypes with high genetic capacity for grain accumulation of micronutrients is widely accepted and most sustainable solution to the problem. However, the breeding approach is a long-term process and may be affected from very low chemical solubility of Zn and Fe in soils due to high pH and low organic matter. Therefore, agronomy-related approaches offer short-term and complementary solutions to the Zn and Fe deficiency in crop production and human health. Soil amendments contributing to solubility of Zn and Fe in soil solution, cereal-legume intercropping systems, and soil and foliar application of micronutrient-containing fertilizers are important agronomic tools which contribute to root uptake, shoot and grain accumulation of Fe and Zn. Addition of organic material had beneficial effect on crop growth, productivity by sustaining soil health. Mixing inorganic salts of micronutrients with different organic materials can enhance the efficacy of micronutrients and enhance wheat productivity. Work conducted by Yadav *et al.*, (2011) revealed that a significant impact of iron and zinc enriched organics were found on soil properties as well as wheat quality and production. However, both the organic sources were found at par towards all the parameters under study. The application of Fe-Zn enriched organics with recommended dose to nitrogen and phosphorus were increased both grain as well as biomass yield of the wheat by 2.3 to 6.6% as compared to direct and by 5.6 to 10.3% as compared to no application of the micronutrients. Similarly, an appreciable improvement in soil organic carbon (28%), available nitrogen (5%) and available phosphorus (22%) was observed which are equivalent or better than control. In contrary, the availability of Fe (5.9 to 18.4 %) and Zn (24.3 to 48.5 %) as well as their uptake (12.9 to 24.1 % for Fe and 13.4 to 28.8 % for Zn) by wheat were appreciably increased by application of Fe-Zn enriched organic as compared to direct and no application of these

micronutrients. Further, it is interesting that availability (10 to 37%) as well as uptake (17 to 32%) of these micronutrients was considerably higher under 50% recommended dose of nitrogen and phosphorus as compared to 100% recommended dose of nitrogen and phosphorus possibly due to antagonistic effect of phosphorus. Hence, this approach would be able to conquer the micronutrient deficiency in the food and human.

Constraints of wheat cultivation

Various observation revealed that, wheat cultivation become constraints in different states in different way for example in West Bengal condition- leaf blight, grain discoloration, termite, *Cyperus* and *Chenopodium album* excessive dominance in crop cafetari, water stress, late sowing, stem borer, poor quality chemicals, poor quality of seed, lodging, low plant population, new disease type (blast like) and rodents become major constraints for production. In bihar - *Phalaris minor*, water logging, late sowing, poor quality seed, bathua, zinc deficiency, wild oat, low plant population, motha (*Cyprus rotundus*), water stress, aphid, poor quality fertilizers, poor quality chemicals, aphid, rodents, termite, hot wind with high velocity during milking stage and stem borer. Similarly in Uttar Pradesh : late sowing, poor quality chemicals, low plant population, broadcasting, poor quality seeds, *Cyperus* and *Chenopodium* poblem, rodents, brown rust, loose smut, water stress, nematode, Zn deficiency, wild oat, *Phalaris minor*, leaf blight, lodging and termite. Throughout in India, wheat production face sever constraints of late sowing and early withdrawal of winter, and this is most common which affect crop phenophase, as per our observation for last ten years. Pre-harvest sprouting (PHS) is one of the major constraints particularly in north east state (Assam) as per my observation during our visit to different part of north eastern state as Wheat monitoring team member, from 2015-17. Germination of wheat within the spike before harvest is called pre-harvest sprouting. Periods of prolonged rainfall and high humidity after the grain has ripened and before it can be harvested can contribute to PHS. PHS can be visualized by kernel swelling, germ discoloration, seed-coat splitting, and the root and shoot emerging. PHS leads to reduced yield and grain quality which

limits end-use applications for wheat result in substantial financial losses to farmers and food processors.

Adoption of resource conservation practices to sustain wheat production

Adoption of improved technologies has been used to reduce some of the adverse impact of nature and enhance the stabilized crop productivity. These technologies which were very simple in earlier years have become more and more complex on account of newly emerging issues related to sustainability and enhancement at higher level of productivity which have been achieved in several regions (Singh *et al.*, 2012). Minimum and zero tillage play critical role in wheat production and very vital for future advance research programme (Mukherjee, 2015b). Zero tillage technology reduces the cost of cultivation, advances time of wheat sowing (4-5 days), requires less water for first irrigation and less infestation of *Phalaris minor*, which is a burning problem in North-West India. After wheat harvest, short duration green gram/cowpea/ green manure/any other crop which can be harvested before the onset of monsoon is viable option for fixing of atmospheric nitrogen through biological nitrogen fixation thereby reducing the N requirement of succeeding wheat crop. The water-use-efficiency could be improved both under transplanted rice as well as rice grown with other new established techniques, and indirectly help to wheat water consumptive use. Application of water based on climatic approach (depth of irrigation water/cumulative pan evaporation value) seems more effective for realizing the high wheat yield. It is inferred that the farmers had perceived that the resource conservation technologies has the potential to decrease the cultivation costs and making rice-wheat system more resource-use-efficient, competitive, sustainable, profitable and environmental friendly. Ladha *et al.*, (2003) supported the findings of the study that the conventional production practices used in the area need to be improved or replaced by resource conserving technologies (RCTs) to adapt to emerging changes and to enhance system productivity, input-use-efficiency, and farm profitability on a sustainable basis. Gupta & Seth (2007) reported that resource conserving technologies (RCTs) such as zero-

tillage (ZT), raised beds, and laser land leveling have been found beneficial in the western indo gangetic plains in reducing cultivation cost, energy consumption and improving crop productivity, input-use efficiency, and farmers' income.

Climate change and wheat production

The impact of climate change in many parts of the world has been explored for different crops (Attri and Rathore 2003). Atmospheric CO₂ concentration increase will have positive effects on crop production especially for C₃ plants through stimulation of photosynthesis and improvement of water use efficiency (Luo *et al.*, 2003). However, under-water deficit and higher temperatures will usually shorten the growth cycle of a given cultivar, and together with reduced water supply are likely to reduce crop production (Turner, 2001). Timely and proper weather forecasting some time help farmer to judge suitable technique for crop cultivation (Mani *et al.*, 2016). Wheat, a C₃ plant species, should benefit from elevated CO₂. However, results of simulation models based on climate change scenarios and the General Circulating Model (GCM) indicate a reduction in the length of the growing season and maturity date in the arid and semi-arid areas of the world (Luo *et al.* 2003), which could cause wheat yield to decline (Whetton 2001). The changing climate is one of the biggest threats to agriculture during the years ahead. This is most challenging and emerging problem and this will effect wheat production in long run (Mukherjee, 2014a). According to estimates, on an average 50% yield losses in agricultural crops are due to different abiotic. The expected changes in the climate could strongly affect the wheat production worldwide. Among various factors affecting wheat productivity, the increase in atmospheric temperature has the most significant effect. Work conducted by Nassiri, *et al.*, 2006 using climate model to know impact of elevated temperature on wheat productivity. Mean monthly weather data values from 1968 – 2000 for 12 major rainfed wheat production areas in north-west and western Iran were used with a climate model, United Kingdom Meteorological Organization (UKMO), to predict the

impact of climate change on rainfed wheat production for years 2025 and 2050. The crop simulation model, World Food Study (WOFOST, v 7.1), at CO₂ concentrations of 425 and 500 ppm and rising air temperature of 2.7 – 4.7°C, projected a significant rainfed wheat yield reduction in 2025 and 2050. Average yield reduction was 18 and 24% for 2025 and 2050, respectively. The yield reduction was related to a rainfall deficit (8.3 – 17.7%) and shortening of the wheat growth period (8 – 36 d). Cultivated land used for rainfed wheat production under the climate change scenarios may be reduced by 15 – 40% (Nassiri *et al.*, 2006). The temperature above optimum shortens the vegetative and reproductive phases of wheat. Generally, the growing degree days (GDD) or heat unit requirement to produce a mature winter wheat crop is approximately 2200, using 4°C as the base temperature. Exposure to heat stress accelerates the development stages in wheat crop which in turn leads to reduced grain yield as well as quality. The high temperature during vegetative stage reduces the number of effective tillers per unit area and during reproductive stages leads to reduced grain number as well as grain weight. Temperature modifies various phase of development of wheat (Table 1). The impact of high temperature on wheat productivity can be minimized by adoption of various agronomic management practices. Adjustment in sowing time is one of the most important agronomic strategies to counteract the adverse effect of temperature stress. In addition, tillage crop establishment methods, residue retention, selection of heat tolerant varieties, water management, and foliar spray of KNO₃, KCl, 1-Methylcyclopropene (1-MCP) and GA can also help mitigating the temperature stress effects (Kajla *et al.*, 2015).

Table 1: Response of development phase to temperature.

Developmental phase	Temperature sensitive stage	Yield reduction due to variation in temperature
Germination	Strongly influenced by temperature	2-5%
Canopy development	Moderately affected by temperature	45-65%
Spikelete	Temperature sensitive	20-30%

production		
Earhead development	Moderately influenced by temperature.	10-15%
Reproductive phase	Slight temperature dependent	5-10%
Dough stage of grain	Temperature sensitive	8-15%

Management practices

In view of the future challenges arising due to global climatic changes, new threats of diseases and pests, new weed flora, herbicide resistance, soil health and stagnated productivity levels, appropriate research strategies need to be developed to further enhance the yield potential and genetic diversity. The genetic variability is the very basis of any crop improvement program. The wild relatives, landraces and genetic stocks are the important sources for new genetic variations. However, it has been viewed that till date, the full potential of genetic resources has not been exploited in crop improvement programs and productivity gains through their use is continuously stagnant and the current efforts on research in the field of wheat hybrids are limited with not much success. Under the changing climate, it is essential to breed short duration varieties with high per day productivity rather than developing long duration high yielding varieties of wheat. Various management options which are very effective for enhancement of yield potential of wheat under changing climate area –

- **Suitable cultivars**

Selection of appropriate variety with respect to date of sowing and expected temperature rise during the crop growth period is necessary to get an optimum yield under high temperature stress conditions (Mukherjee, 2008). The new varieties of wheat should possess genes/QTLs responsible for providing resistance/tolerance not only to major diseases and insect-pests, but also to have tolerance to terminal heat, drought, salinity-alkalinity and cold. The nature's gift in the form of vast fertile tract of Indo-Gangetic plains alone offers ample opportunity for enhancing food production to a much higher level. However, wheat breeding in combination with agronomic manipulation for exploiting the positive interactions between genotype and cropping systems management also has great potential.

Varieties like HD 2967, PBW 343 and DBW-39 have flexibility (Table 2), adaptability and are suited to different sowing times and also well suited to normal and early (October) sowing time. The variety PBW-343 was released for the northwestern India primarily because of its wider adaptability in terms of temperature and water stress tolerance. DBW-17, PBW-343 and PBW-502 have comparable yield results when sown under the late conditions. PBW-343 was the predominant in the rice-wheat growing areas, where sowing can often be delayed because of later harvest of second rice crop and/or managing stubble from the rice crop (Malik *et al.*, 2007). Under this situation zero till seeding of the wheat provides the opportunity for achieving an earlier sowing of the wheat crop. C-306 performed best when sown early, and gave poor yield under late sowing conditions, whereas early sowing of high yielding varieties that are suited across sowing time (like PBW-343 and PBW-502) allows longer maturation time and earlier anthesis, thus reduces high temperature exposure to wheat crop (Coventry *et al.*, 2011).

- **Sowing time**

Time of sowing is one of the non-monetary inputs for getting optimum yield in wheat crop. Selecting optimum planting time, avoids high temperature stress during anthesis and grain filling. High temperature at that time shortens the season and reduces yield. Adjust sowing time so that crop escapes to hot and desiccating wind during grain filling period. The growth and development in wheat crop varies with date of sowing. The optimum time of sowing for wheat crop in India is first fortnight of November. The delay in sowing of crop is mainly because of late harvest of paddy crop, delay in field operations, which results in sowing of crop upto first fortnight of January. Work conducted by author during the 2014-16 under the aegis of Bidhan Chandra Krishi Viswavidyalaya, revealed that plant height and effective tiller /m²

decreases with delay in sowing from timely (20th November) to late (25th December) . Crop sown in mid November shows better growth and maximum plant height than rest of sowing dates which is followed by late November and December sowing (Table 2). The reason for this difference is the rise in temperature which makes the crop to enter into the next stage without much development required for the succeeding stage. Due to lowering of temperature cell activity like cell division and expansion, decrease this leads to poor yield and yield attributing characters and ultimately influence the B:C ratio. Good yield and better B:C ratio observed with early sowing with cultivar of K0307 and HD 2967 (Table 2).

Table 2: Effect of various sowing time and cultivar on yield and yield attributing character of wheat.

Treatments	Plant height (cm)	Effective tiller/m ² (no.)	Grain / ear (no.)	Ear length (cm)	Test weight (g)	Yield (q/ha)		B:C ratio
						Grain	Straw	
10 th November	97.33	365.55	42.36	8.32	42.36	36.69	56.69	1.78
25 th November	93.68	325.65	44.32	8.36	41.23	32.05	61.26	1.66
10 th December	90.26	265.25	39.45	7.98	38.45	22.36	45.36	1.48
25 th December	74.36	184.33	31.02	6.32	36.25	16.36	37.15	0.93
S.Em±	1.58	3.44	0.56	0.10	0.19	1.31	1.44	-
C.D. (P=0.05)	4.56	10.65	1.21	0.29	0.58	4.23	4.63	-
Cultivars								
DBW 107	93.65	253.11	31.26	7.89	36.21	24.56	41.23	1.02
HD 2967	94.65	302.65	42.36	8.12	41.36	37.25	56.98	1.61
DBW 39	97.89	305.33	38.12	8.97	40.32	32.11	62.36	1.23
K0307	101.26	311.22	39.32	9.01	43.21	36.35	60.66	1.62
S.Em±	2.3	5.98	0.45	0.13	0.21	1.23	1.41	-
C.D. (P=0.05)	6.23	15.11	1.25	0.36	0.65	3.65	5.25	-

- **Conservation agriculture practices**

Adopting CA system (includes planting on raised beds) offers opportunities for crop diversification (Mukherjee, 2016a). Cropping sequences/rotations and agroforestry systems when adopted in

appropriate spatial and temporal patterns can further enhance natural ecological processes which contribute to system resilience and reduced vulnerability to yield reducing disease/pest problems. Limited studies indicate that a variety of crops like wheat, mustard, chickpea, pigeonpea etc., could be well adapted to the new systems with advantage. CA involving zero-till and surface managed crop residue systems are an excellent opportunity to eliminate burning of crop residues just after wheat or rice, which contribute to large amount of green house gases like CO₂, CO, NO₂, SO₂ and large amount of particulate matter. Burning of crop residues, also contributes to considerable loss of plant nutrients, which could be recycled when properly managed.

- **Resource improvement**

Type of tillage options and planting methods exhibits an important role in better emergence and subsequent crop growth. Sowing of wheat crop using different tillage options depends upon type of soil, sowing time and irrigation water availability. No tillage when combined with surface managed crop residues sets in the processes whereby slow decomposition of residues results in soil structural improvement and increased recycling and availability of plant nutrients (Mukherjee, 2015). Surface residues acting as mulch, moderate soil temperatures, reduce evaporation, improve biological activity and provide more favorable environment for root growth, the benefits which are traditionally sought from tillage operations. In no-till and zero tillage system there is minimum disturbance to soil regime and maintenance of plant residues. The presence of mulch/ crop residues protect seedlings from high temperature during its initial growth period and keeps soil temperature down during the day and reduces cooling at night and also helps in conserving moisture (Mukherjee, 2008a). This helps the plant to carry out its metabolic activity with the same pace as required for its optimum growth i.e. without reducing its growth period.

Also the transpiration process get increased with increase in soil temperature, which in turn reduces the canopy temperature and thus helps in overcoming the terminal heat stress in plant. As the time period to maturity is delayed, so the senescence in plant.

- **Nutrient management**

It is quite clear that the current approach of fixed-rate, fixed-time fertilizer recommendations made for large areas cannot be successful under intensive cropping mainly because this approach does not take into account the existence of large variability in soil nutrient supply and crop response to nutrients present in our farming system. Several researchers have highlighted falling productivity and nutrient use efficiency, multi-nutrient deficiencies, high extent of nutrient mining and falling farm income as the consequences of generalized recommendation in a highly variable landscape (Ghosh et al., 2004; Tiwari, 2007, Mukherjee, 2016). Naidu et al. (2008) in their recent study observed different potential, limitations and response to management for various crops in different parts of the country, and suggested the necessity of soil-test based nutrient application. Besides the above, imbalanced and inadequate nutrient application by farmers is one of the major reasons for wheat yield loss and associated economic and environmental risks. Surveys in the Indo-Gangetic Plains (IGP) revealed that farmers often apply greater than recommended rates of fertilizer N and P, but ignore the sufficient application of other nutrients (Singh et al., 2010). Potassium, sulfur, and micronutrients are not applied in adequate amounts to prevent increasing deficiencies of these nutrients. Sanyal et al. (2010) also pointed out the lack of potassium application as one of reasons for yield stagnation in the rice-wheat system in the IGP. The risk of nutrient mining can be particularly serious in highly productive areas and relatively lower levels of input of K, S, and micronutrients (Singh et al., 2010). Such

unbalanced and inadequate use of nutrients can decrease the profitability with increased environmental risks associated with loss of excess N from the root zone (Prasad, 2006). Site-specific nutrient management (SSNM) provides an approach to “feeding” crops with nutrients as and when they are needed (Mukherjee, 2017a). It ensures that all the required nutrients are applied at the proper rate and in proper ratio based on the crop’s nutrient needs. The principles of SSNM are well established and have produced yield and quality improvement in wheat across soils and regions. Recent studies on SSNM in wheat have looked into the aspect of real time N management for optimizing the efficiency of N. N use efficiency (NUE) in wheat is low and a recent worldwide evaluation showed that N recovery efficiency is just 30%. The main reason for low NUE is inefficient splitting of N applications advocated in the current recommendations, as well as the use of N in excess to the requirements (Mukherjee, 2014b). Such excessive use of N is often associated with wrong perception of farmers, where yellowing of wheat plants due to a different abiotic stress is interpreted as nitrogen deficiency symptoms (Dhadli *et al.*, 2010). On the contrary, optimum use of N can be achieved by matching N supply with crop demand, where appropriate amount of N is applied at the right physiological stage of nutrient demand. A potential solution is to regulate the timing of N application in wheat using a chlorophyll meter (or SPAD meter) or a LCC to determine the plant N needs. Such approach brings in the location specificity in terms of N supplying capacity of the soil and allows varying N application according to crop requirement, as opposed to the standard practice of fixed-time N management. The concept is based on results that show a close link between leaf chlorophyll content and leaf N content.

- **Water management**

High temperature damage is commonly associated with water stress so water management is critical. As long as plants can transpire freely they cope with high temperature. Field crops provided with sufficient water can withstand air temperatures to 40°C. But if water is limiting, 40°C will kill leaves. The reason for this is that water-stressed plants attempt to conserve water by closing their stomata, as a consequence evaporative cooling diminishes and, without that cooling, leaf temperatures might approach 50°C and at that temperature plant processes break down (wheatdoctor.org/high-temperature). Scheduling irrigation according to growth stages of crop, use of efficient irrigation methods, providing extra irrigation if available and irrigation based on moisture status of soil results in higher grain yield by alleviating the effect of high temperature in wheat crop. Seedlings grown in very hot dry soils can readily reach the critical temperature. The use of sprinkler irrigation under such conditions helps in reducing high soil temperature by irrigating at that time and irrigating the crop during evening time helps the crop to recover from day heat stress, thus reducing heat losses and increases the yield of the crop. To minimize the effect of high temperature at other stages of crop one should ensure that the crop is not water stressed (Mukherjee, 2014). Tolk *et al.*, (1995) found that vapor pressure deficit (VPD) and canopy temperature decreased significantly during and following sprinkler irrigation.

- **Weed management**

Weeds infestation is one of the major biotic constraints in wheat production. Wheat is infested with diverse type of weed flora, as it is grown under diverse agroclimatic conditions, different cropping sequence, tillage and irrigation regimes. Weeds compete with crop for light, nutrient and water (Singh *et al.*, 2004). The yield losses due to

weeds vary depending on the weed species, their density and environmental factors. In wheat yield reduction upto more than 30-65% reported (Singh, et al., 2003) For control of diverse weed flora in wheat combination of herbicides either as tank mixture, if compatible (sulfosulfuron + metsulfuron; mesosulfuron + iodosulfuron) or as sequential, if not compatible (fenoxaprop or clodinafop or pinoxaden with metsulfuron or 2, 4-D) are required. Further, the herbicide efficacy can be improved by use of adjuvants, safeners and proper spray technology. A greater focus on spray technology by imparting training to growers, field functionaries and industry personnel is required. However, sole dependence on herbicides is also not desirable as it contributes to shift towards difficult-to-control weeds and the rapid evolution of herbicide resistance, which is a threat for sustainable wheat production. Due to changing climate situation weed pattern shifted in vigorous way, which is become threat to our national food basket stock (Mukherjee, 2017). Presently some of P. minor populations have shown the evolution of multiple herbicide resistance across three modes of action (Photosynthesis at photosystem II site A, ACCase and ALS inhibitor). However, for efficient weed management, the non-chemical weed management tactics should be adopted in conjunction with chemicals (like herbicide mixture and rotation, optimum spray time, dose and methods). Some of the non-chemical agronomic strategies like tillage, sowing time, sowing methods, competitive crop cultivars, higher crop density, closer spacing, irrigation, fertilization, crop rotation and sanitation practices (weed-free crop seeds and manure) can be adjusted and adopted in such a

manner that they provide the competitive edge to the crop over weeds. As the introduction of herbicide having new mode of action has slowed down, therefore, there is need to revive some of the old herbicides (viz. pendimethalin and trifluralin) as well as to develop wheat varieties tolerant to less selective herbicides like metribuzin and resistant to non-selective herbicides like glyphosate and glufosinate. Integration of knowledge of weed biology and non-chemical methods of weed control with chemical methods will help in increasing the life of existing herbicides and make the weed management cost-effective and efficient (Chokker et al., 2012). Few of the most promising herbicide (Table 3), which play vital role in enhancing wheat production, through right time and proper application measures.

Table 3: Promising herbicides for control of different types of weeds in wheat

Weed flora	Herbicides	Dose (a.i./ha) Product dose	Time of application
Grasses	Clodinafop	60	Post emergence 24 - 30 DAS
	Fenoxaprop-ethyl	100-120	Post emergence 30-35 DAS
	Pinoxaden	25	Post emergence 30-35 DAS
	Sulfosulfuron	1000	Post emergence 30-35 DAS
	Isoproturon	1000-1500	Post emergence 30-35 DAS
	Pendimethalin		Pre-emergence 1-3 DAS
Broad-leaved weeds	2,4-D-E	500	Post emergence 30-35 DAS
	Metsulfuron	4	Post emergence 30-35 DAS
	Carfentrazone	20	Post emergence 30-35 DAS
	Pendimethalin	1000-1500	Pre-emergence 1-3 DAS

DAS = Days after sowing.

Building a systems perspective in research of all above point will be fundamental in generating and promoting new technologies for higher yield of wheat. A systems perspective is best built working in partnership with farmers who are at the core of farming system, with scientists, farmers, extension agents and other stakeholders working in partnership mode will therefore be critical in developing and promoting new technologies. Disseminating of knowledge through result

demonstration become very vital for improvement of crop production. Understanding system interactions and developing management strategies will call for teams of scientists across disciplines working together for wheat improvement programme. This will also call for new ways of managing and leveraging funding mechanisms to permit working together of various stakeholders to facilitate information exchange and learning.

CONCLUSION

Wheat is one of the most vital crops in India and word as a whole. This has good contribution in world cereals based food basket. The world would require around 840 million tonnes of wheat by 2050 from current production level of 642 million tones and it has to be achieved with less land and resources through genetic, physiological and agronomic interventions particularly resource conservation technologies. Besides, precision breeding for improving varietal elasticity, new initiatives for climate change monitors and crop modeling for advance yield forecasts would help in fulfilling future demands. The future strategies to mitigate adverse effects of climatic change, threat of new and emerging diseases, pests and weed flora, including the issue of increased herbicide resistance, deteriorating soil health need to be implemented to enhance genetic yield potential and sustainability. Future research programme should be explore more options to increase yield components through photosynthetic capacity and efficiency, introduction of C₄ like traits-carbon concentrating mechanism, improving light interception, optimizing spike and canopy photosynthesis in future genotypes.

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