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Increasing Wheat Productivity under Variable and Changing Climatic Conditions in West Bengal, India

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Abstract

Wheat is the second important cereal crop after rice in West Bengal. However, its area of cultivation and production remain almost stagnant in recent years due to lower productivity of the crop. Inter seasonal climatic variability is one of the most important reasons behind it. Thus, there is a need to find out suitable management options against such climatic variability, to boost up the productivity. In this study DSSAT 4.5 model was used to simulate the potential yield of wheat for Nadia district for 30 years (1982 to 2011). The long term district wheat yield was also collected for its comparison. The attainable yield with proper agronomic management practices was collected from research experiment conducted at Bidhan Chndra Krishi Viswavidyalaya, for yield gap analysis. Wheat yield was also simulated under five number of irrigation treatments. Result revealed that the potential yield ranges from 5101 to 10128 kg ha^{-1} with an average of 8458 kg ha^{-1}. The average yield produced in research field was 4151 kg ha^{-1} and long term average actual district yield was 2316 kg ha^{-1}. Thus, there is ample scope to reduce the yield gap by around 80% to reach the attainable (research) yield, only through optimization of different crop management techniques. The result of the irrigation experiment showed that wheat yield increased with increase in number of irrigations. But exceptionally, three number of irrigations produced less yield than that of two numbers of irrigation due to water stress in critical crop growth period.

Keywords: wheat, climatic variability, Irrigation, DSSAT

1. Introduction

Rice and wheat are two major food crops in India in general and West Bengal (WB) in particular. Therefore, emphasis should be given on improving and sustaining the productivity of these crops towards food security of this state (Sarkar et al., 2013). After ‘Green Revolution’ higher productivity hence higher profitability leads towards higher area expansion under wheat crop in different district under WB up to the end of 1980s (Pal and Mukhopadhyay, 1980), follo wed by drastic reduction of area during 90s’ and remained almost stable during recent year (Economic review, 2011−12). But overall productivity of the wheat crop increased gradually with some inter-year variability due to weather fluctuation. Temperature is one of the important weather elements that regulate the growth and yield of many crops (Kurek et al., 2007). High temperature stress is an important yield limiting factor in wheat in most of the wheat growing areas (Prasad et al., 2008). In India studies have also shown a trend for increasing air temperature (Sing and Sontakke, 2002). The rainfall amount in October and November month has shown an increasing trend during 1990−2000 compared to earlier years (Mukherjee and Banerjee, 2009), thus there is a chance of late sowing of winter wheat because of delay in land preparation. On the other hand, share of irrigation to agriculture is diminishing very quickly. Uneven distribution of rainfall and extreme events aggravated the situation. The biggest threat to sustain the rice-wheat productivity in south Asia is water shortage during critical crop growth stages (Subhas and Mohan, 2012). Thus, weather abnormality, untimely sowing, lack of irrigation and low fertilizer use is becoming the major constraints for wheat cultivation in WB situation.

2. Materials and Methods

2.1. Study area

The study was conducted in Nadia district, which falls under New Alluvial Zone of West Bengal and characterised by 1400 mm annual rainfall with 31.9 and 20.4 °C average annual maximum and minimum temperature. Wheat growing season extended from middle of November to end of April month.

2.2. Concept and calculation of yield Gap

The yield gap is defined as the difference between the yield under optimum management (generally under research field) and the average yield achieved by farmers (Editorial, Field Crop Research 2013). It is a powerful method of understanding the biophysical opportunities to meet the projected increase in demand for agricultural products and to support decision making on research, policies and development. During last decades the yield has become almost stagnant and there are large gaps between potential yield, research yield (attainable) and farmers' (district) yield (Ladha et al., 2003). The difference may be caused by different factors which are not transferable, such as environmental condition and optimum management practices adopted in research field.

The major portion of farming community in WB is marginal. It is very difficult to them to follow optimum crop management practices (e.g. sowing time, irrigation and fertilizer amount and application timing, other agronomic managements) due to poor availability of infrastructural facility and resources. Progressive farmers can produce yield at attainable level by maintaining recommended package and practices. District yield is calculated considering a large number of farmers (small, marginal and progressive) productivity of particular crops. Thus, there is always a gap between research yield and farmers' yield.

The Decision Support System for Agrotechnology Transfer (DSSAT 4.5) includes the Cropping System Model (CSM)-CERES-Wheat model, which can be used to simulate the growth and development of rain-fed and irrigated wheat worldwide (Jones et al., 2003). In this study DSSAT 4.5 model was used to simulate the potential yield of wheat for Nadia district for 30 years (1982 to 2011). The long term (1982 to 2011) actual wheat yield data (average yield from farmers'field) for Nadia district was collected from the Evaluation Wing, Govt. of WB.

2.3. Simulation under different water regimes

Wheat yield was simulated under different number of irrigation treatments through CERES-Wheat crop model in the DSSAT 4.5 platform. The variety was PBW-343. The genetic coefficient of this variety was collected from BCKV Annual Progress Report (2014–15) of FASAL project, Kalyani. In this virtual experiment five (1, 2, 3, 4, 5) number irrigations were allotted in T_1 to T_5 treatment respectively. The depth of each irrigation was 30 mm. Irrigation was applied as per Table 1.

3. Results and Discussion

3.1. Yield gap and actual trend of wheat yield

The potential yield ranges from 5101 to 10128 Kg ha^{-1} with an average of 8458 Kg ha^{-1} (Figure 1). A sudden decline of potential yield during 2004 may be associated with a high minimum temperature (25.3 °C) at grain filling stage, compared to previous year (21.9 °C).

Table 1: Irrigation scheduling for different treatments

Treatments	No. of irrigation	No. of irrigation				
		20	35	55	75	95
T_1	1		√			
T_2	2		√		√	
T_3	3	√	√			√
T_4	4	√	√	√		√
T_5	5	√	√	√	√	√

The yield of wheat from a research experiment conducted at Kalyani, Nadia, WB was 4280 and 4022 kg ha^{-1} during 2011–12 and 2012–13 respectively (Lalmalsawmi, 2013). The average yield (4151 kg ha^{-1}) of this experimentation was considered as the average research yield (Figure 1) of the Nadia district. During 1983, the actual yield was 3159 kg ha^{-1}, which declined gradually with years and the average actual yield remained as 2488, 2140 and 2331 Kg ha^{-1} respectively during 1980-89,

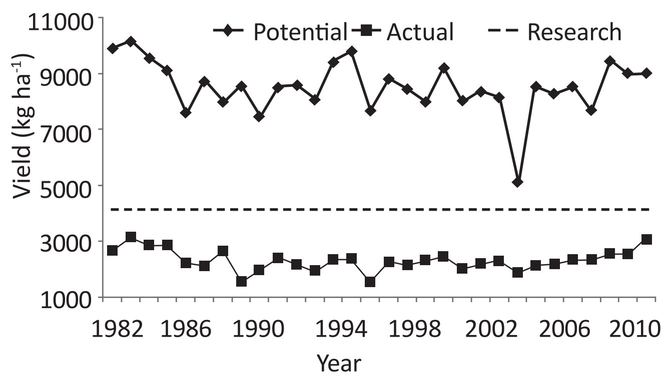

Figure 1: Potential, Research and Actual yield of wheat in Nadia district, WB, India

1990–99 and 2000–2009. A steep increase in actual yield during 2011 is associated with prolonged winter season. Thus, there is an ample scope to increase the actual yield by 80% to reach the attainable yield, only through optimization of different crop management techniques.

3.2. Bridging the yield gap considering temperature constraint

Major constraints to wheat grain yield include high temperatures during grain filling (Andarzian et al., 2008). Thus proper time of sowing is needed to coincide the sensitive stages of the crop to optimum temperature level. Analysis of long term temperature data along with research experimentations can be used to fix the optimum time of sowing. The optimum time of sowing of wheat in WB condition is 3rd week of November (Anonymous, 2012) under irrigated condition and 25th October to 10th November under rain-fed condition.

Parya (2009) observed in the Research Farm of Bidhan Chandra Krishi Viswavidyalaya (BCKV), Jaguli, Nadia, that 18th November sown wheat crop produced the highest yield

(Table 2) due to superiority of yield attributing characters over other dates of sowing. Increase in maximum and minimum temperature (1.88 and 1.36 °C) during the post flowering stages under delayed sowing might have reduced the duration of grain filling period which led to reduction in yield. On an average 1st week of December sown crop produced 6.5% less yield. However, 15 days more delay increase the reduction by 26.5%. Similarly in BCKV Research Farm, Gayespur, Nadia, Thentu (2016) recorded maximum wheat yield when sowing was done during 3rd week of November and with delay in sowing (up to 10 December) yield reduced to the tune of 3.2 to 5.3% (Figure 2). The reduction was 9% when the crop was sown on 20th December.

Table 2: Effect of dates of sowing on yield (kg ha^{-1}) of wheat cultivars (average of 3 years, 2005−08)

Varieties	Dates of sowing		
	18th November	3rd December	18th December
PBW343	2730	2680	1840
HD2733	2850	2890	2410
HW2045	2530	2380	1840
PBW533	3540	3060	2610
K9107	3780	3400	2630
Mean	3090	2890	2270

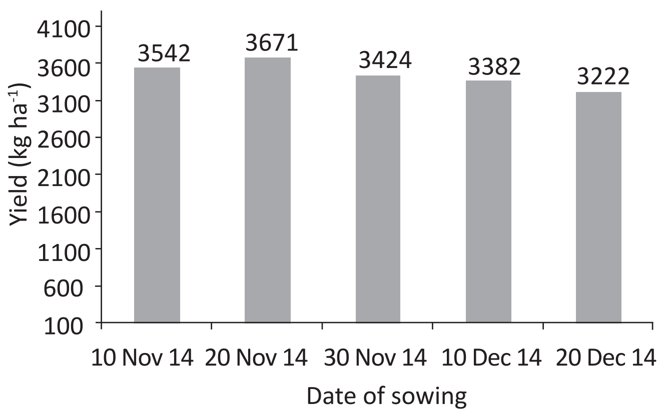

Figure 2: Impact of date of sowing on yield of wheat in Nadia district, WB, India

3.3. Irrigation management for yield improvement

Wheat is a highly water sensitive crop. Water stress reduces the crop yield to different scale depending on the stage(s) of water stress. Water deficit during stem elongation and heading stage resulted significant decrease in yield. Thus, irrigation could be skipped during milking stage to minimize the yield loss (Tari, 2016). After starting with sufficient pre-sowing soil moisture level, a single irrigation of 60 mm of water at stem elongation stage can achieve high water use efficiency with only 5% yield reduction from no-water stress treatment (Xu et al., 2016). Lalmalsawmi (2013), in New Alluvial Zone of WB pointed out that, according to water sensitivity the growth stages of wheat are in the order: Flowering>Maximum Tillering>CRI>Milking.

The result of the modelling experiment showed that wheat yield increased with increase in number of irrigations (Figure 3). Exceptionally T_3 (3 numbers of irrigation) produced 2.6% less yield compared to T_2 (2 numbers of irrigation). Model output showed that the crop under T_3 exposed to water stress (0.29) during end of ear growth (Table 3), which might be possible reason for getting low yield compare to T_2 irrigation treatment. Thus, under limited water resource proper timing of irrigation plays a vital role. Although the highest yield was obtained under T_5, but the crop under this treatment also faced water stress during later part of grain filling period. Depth of irrigation should be considered along with the time of irrigation.

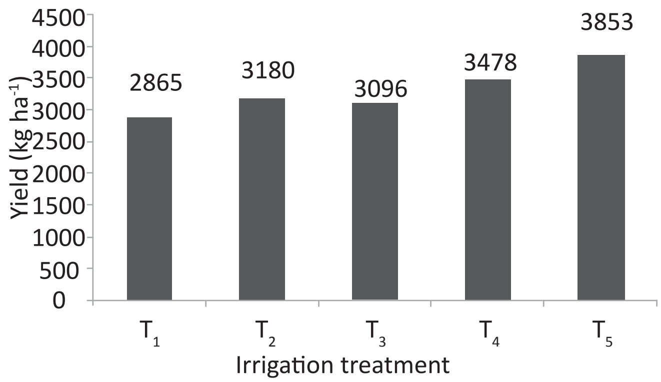

Figure 3: Variation of wheat yield under different irrigation treatments, Kalyani, Nadia, WB, India

Table 3: Water stress (0−1 scale, where 1=maximum stress) in different growth stages of the crop

Stage	No. of irrigation				
	One	Two	Three	Four	Five
End EAR growth	0.47		0.29		
Beginning of grain filling	0.74	0.58	0.51	0.35	0.04
End of grain filling	0.63	0.74	0.63	0.63	0.60

3.4. Dissemination of the weather based crop management strategies

India Meteorological Department in collaboration with different State Agricultural Universities and Indian Council of Agricultural Research Institutes, is providing weather based agro-advisories to the farming community directly through mobile sms, Krishi Vigyan Kendra, Block office, print and electronic media. Integration of crop management strategies under variable and changing climatic situation, generated through crop growth simulation modelling, with existing advisory will go long way to improve wheat productivity.

4. Conclusion

Flowering and grain filling stages of wheat are highly sensitive to temperature variability and water stress. Agro-climatic analysis assists in screening of suitable wheat growing locations. Crop growth simulation models are effective tools to find out optimum crop management practices. Information generated through agro-climatic and modelling research incorporated in the existing agro-met advisory bulletin will help improve the decision making process of the farming community.

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