MAUSAM, **73**, 1 (January 2022), 189-192

633.11 (540.27)

FAO AquaCrop model for determining optimum wheat sowing date in *Tarai* region of Uttarakhand

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(*Received 4 August 2020, Accepted 29 September 2021*)

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सार – विशिष्ट कृषि जलवायु परिस्थितियों(नैन, 2016, पात्रा एट ऑल, 2017) के तहत फसल की उपज क्षमता को अधिकतम करने के लिए आदर्श बुवाई अवधि महत्वपूर्ण है। यह फसल के विकास के फीनोलॉजिकल चरणों को प्रभावित करता है और परिणामस्वरूप, बायोमास का आर्थिक उपज में कुशल रूपांतरण होता है। रबी 2013-14 के दौरान, गोविन्द वल्लभ पन्त कृषि एवं प्रोधोगिकी विश्वविद्यालय के डॉ. एन. ई. बोरलॉग फसल अनुसंधान केंद्र में एक्वाक्रॉप मॉडल के द्वारा गेहूं की फसल के लिए सर्वोत्तम बुवाई तिथियां निर्धारित करने के लिए एक क्षेत्र अनुसंधान किया गया। एक्वाक्रॉप मॉडल को तीन बुवाई तिथियों - 3 दिसंबर, 18 दिसंबर और 3जनवरी के लिए वानस्पतिक और आर्थिक उपज के लिए अंशांकित किया गयाहै। एक्वाक्रॉपमॉडल के अंशांकन के बाद, अंशांकित गुणांकों का एक समूह प्राप्त किया गया(पारीक एट ऑल, 2017। अंशांकित एक्वाक्रॉप मॉडल का उपयोग कर लगातार तीन वर्षों के लिए (2010-11, 2011-12 और 2012-13) गेहूंकी उपज और बायोमास को सत्यापित किया गया। मॉडल का उपयोग विभिन्न बुवाई तिथियों के लिए उपज प्राप्त करने के लिए किया। सभी परीक्षण वर्षों के लिए, एक्वाक्रॉप मॉडल के सिमुलेशन निष्कर्षों ने फसल की पैदावार और गेहूं के बायोमास को दर्शाया। मॉडल का उपयोग अलग-अलग बुवाई की तारीखों के आधार पर इष्टतम बुवाई सप्ताह का चयन करने के लिए किया गया था और 10 वर्षों की अवधि के लिए उपज प्राप्त की गयी(मलिकएट ऑल, 2013)। गेहूँ की औसत और सुनिश्चित उपज की गणना संभाव्यता विश्लेषण (60,75 और 90%) के आधार पर की गई थी।उत्तराखंड के तराई क्षेत्र के लिए इष्टतम बुवाई का समय नवंबर के पहले सप्ताह एवं दूसरे सप्ताह (नैन, 2016) के दौरान सुझाया गया। नवंबर के तीसरे सप्ताह में और उसके बाद बुवाई से औसत उपज कम(नैन, 2016) प्राप्त होती हैं। अध्ययन की खोज से उत्तराखंड के तराई क्षेत्र में गेहूं की फसल की उत्पादकता और उत्पादन बढ़ाने में मदद मिलेगी।

ABSTRACT. The ideal sowing period is critical for maximizing the crop's yield potential under specific agroclimatic conditions (Nain, 2016; Patra *et al*., 2017). It influences the phenological stages of the crop's development and, as a result, the efficient conversion of biomass into economic yield. During rabi 2013-14, a field research was done at GBPUA&T's Borlaug Crop Research Centre to determine the best sowing dates for wheat crops employing Aquacrop model. Aquacrop model has been calibrated against vegetative and economic yield forthree sowing dates, *viz*., 3rd December, 18th December and 3rd January (Pareek *et al*., 2017). After calibrating the Aquacrop model, a set of conservative variables was obtained (Pareek *et al*., 2017). Afterward, the calibrated Aquacrop model was used to validate wheat yield and biomass for three years in a row, namely 2010-11, 2011-12 and 2012-13. The model subsequently used to simulate yield under different sowing dates. For all of the tested years, the simulation findings of the Aquacrop model reflected the observed crop yields and biomass of wheat. The model was used to simulate the optimum sowing week based on varying sowing dates and produced grain yield for a period of 10 years (Malik *et al*., 2013). The average and assured yield of wheat was worked out based on probability analysis (60, 75 and 90%). The optimum sowing time for *Tarai* region of Uttarakhand was suggested as first week of November followed by second week of November (Nain, 2016). In no case wheat should be sown during third week of November and beyond due to poor assured yield and average yield (Nain, 2016). The finding of the studies will help to increase productivity and production of wheat crop in *Tarai* region of Uttarakhand.

Key words – Aquacrop, Calibration, Validation, Wheat, Sowing date, Simulation & *Tarai* region.

1. Introduction

Agriculture practices are the backbone of Indian economy, as it offers employment to over 60 percent of the population (Arjun, 2013). Indian agriculture sectors have registered remarkable growth over last few decades and have helped Indian agriculture mark its presence at global level. India is currently the world's second largest wheat producer after China, accounting for more than 12% of total global wheat production. India is now a wheat surplus country with the ability to export wheat on the international market for a large exchange of foreign money. Wheat growing area has been increased to about more than 30 Million hectare with 2.98 tonnes/ha normal National productivity. The major Wheat producing States are Uttar Pradesh, Punjab, Haryana, Uttarakhand, Bihar, west Bengal and Himachal Pradesh;in Northern parts while Madhya Pradesh, Rajasthan, Maharashtra, Gujarat and Karnataka in central and southern parts. These States have more than 99% contribution in total Wheat production in the country. Being a temperature sensitive crop, the phenophases and productivity of wheat crop is significantly affected due to date of sowing (Kumar *et al*., 2013). The choice of sowing date can be identified as crucial management option to optimize grain yield (Randhawa *et al*., 1981). In India, experiments are being conducted by agronomists and breeders for decades to optimize sowing dates for different cultivars under different climatic regions based on their yield (Aggarwal *et al*., 1994). Wheat is one the major crop grown in *rabi* season (October to April) after the harvest of *kharif* crops of rice or cotton. Sowing dates for wheat crop in major growing states are within the optimal sowing window and ranged in between end of month October to mid of month November. But occasionally the sowing of wheat in India gets delayed due to the delay in harvesting of *kharif* crops of the sequence (Ortiz-Monasterio *et al.*, 1994). The FAO proposed the Aquacrop model in 2009, with a thorough explanation provided by Steduto *et al*., 2009 and Raes *et al*., 2009. The Aquacrop model assists in determining the crop yield that may be predicted in a particular environment. The user specifies environmental data as input used during estimation, which include weather parameters such as rainfall, air temperature and the evaporative requirement of the atmosphere, soil and plant characteristics and field management procedures (Deryng, *et al*., 2011). By adjusting the environmental inputs, the predicted crop output and yield can be simulated for various environmental circumstances. The impact on yield under various climate change scenarios can be evaluated using the model by entering expected weather conditions and expected annual mean atmospheric CO_2 concentrations. Wheat is an important staple crop grown throughout India, however it is frequently cultivated after the optimum yield window in many regions (Lobell *et al*., 2012). Present paper is an attempt to identify optimum sowing dates of wheat cultivation for better productivity under *Tarai* region using Aquacrop model.

2. Materials & methodology

2.1. *Field experimentation*

The on farm trial was carried out in N.E. Borlaug Crop Research Centre (29.02°N,79.48°E and 243.83m a.m.s.l) of the GBPUA&T, Uttarakhand). There were three treatments of sowing date at an interval of 15 days. Sowing in first, second and third treatment was done on 3rd December, 18th December and 3rd January respectively. Wheat crop was uniformly fertilized with 150 kilogram Nitrogen, 60 kilogram P_2O_5 and K_2O 40 kilogram per hectare in the forms of urea and PK fertilizer. 50 percent dose of Nitrogen and full dose of Phosphorus and potash were applied during tillering stage and remaining 50 percent dose was supplied during the tillering stage, with the remaining half applied during the crop's ear head development stage. The occurrence of phenological events like emergence, crown root initiation, tillering, jointing, flowering, maximum canopy cover, milking dough and maturity were recorded. The weather parameters required by the AquaCrop model are the daily values of minimum and maximum temperature, bright sunshine hours, relative humidity, rainfall and pan evaporation (Steduto *et al*., 2009). The data pertaining to present experiment was collected for a period of 10 years (2004-14) from the weather station located at the Borlaug Crop Research Centre (GBPUAT).The soil of the whole field belongs to Patharchatta Series. There were two horizons in experimental field named -sandy loam and silty clay loam.

2.2. *Calibration & validation of AquaCrop model*

Aquacrop model used for present experiment simulates yield with varying water regime has been calibrated for winter wheat using experimental findings of 2013-14 cropping season. The calibration was performed against vegetative and economic yield for the three treatments of sowing dates *viz.*, 3rd December, 18th December and 3rd January. After calibrating the Aquacrop model, a set of restrictive variables were obtained and employed to validate wheat yield and biomass for three consecutive years, namely 2010-11, 2011-12 and 2012-13. The model was then used to simulate yield under various sowing dates chosen for the study. The findings of the Aquacrop model simulation results for all of the above-mentioned years were consistent with the reported grain yield and biomass of wheat.

TABLE 1

Optimum sowing week for past 10 years as simulated by Aquacrop model

Year	Optimum week	Biomass (ton/ha)	Yield(ton/ha)
2004-05	14 Nov-20 Nov	16.06	4.65
2005-06	19Nov - 25 Nov	14.63	4.96
2006-07	15Nov-21 Nov	16.60	5.10
2007-08	14Nov-20Nov	13.70	3.59
2008-09	14 Nov-20Nov	15.29	5.21
2009-10	1 Nov-7 Nov	14.85	5.16
2010-11	7 Nov-13 Nov	15.08	5.23
2011-12	7 Nov-13Nov	15.11	5.25
2012-13	1 Nov-7Nov	15.21	5.19
2013-14	14 Nov-20 Nov	15.29	5.21

2.3. *Optimization of sowing date of wheat crop*

The optimum sowing dates of wheat crop in *Tarai* region worked out using meteorological data of past 10 years and prescribing the package of practices given by the scientists of GBPUA&T, for the region. Calibrated & validated Aquacrop model was first run at an interval of one week in order to find out the week with maximum productivity. Thereafter Aquacrop model was used at an interval of one day (within the optimum week) to narrow down the optimum dates of wheat sowing. After calculating optimum dates of wheat sowing for past 10 years (2004-2014), probability analysis was performed by using 'Ranking order method' suggested by Doorenbos and Pruitt (1984). Optimum dates of wheat sowing as simulated by model for ten years arranged in the descending order on the basis of amount of yield. This was done into a column and named it 'Yield'. A number was assigned to each record. This is called ranking number (m). Probability number Fa (m) was assigned to these ranking numbers as follow :

Fa (m) = 100m/n+1

where,

m = rank number,

n = number of records

3. Results and discussion

The optimum sowing dates of wheat crop in *Tarai* region were determined by using meteorological data set of Pantnagar from 2004-05 to 2013-14 and prescribed package of practices for wheat by scientists of G.B. Pant University. To achieve this objective at first Aquacrop model was used to simulate the data at an interval of one week in order to find out the week with maximum productivity. Thereafter Aquacrop model run at an interval of one day (within the optimum week) to narrow down the optimum dates of wheat for the study area. Table 1 represents optimum weeks for the different years. Aquacrop model initially simulated the optimum sowing week based on sowing dates produced higher yield. Then optimum sowing dates were identified through yield categorization.

TABLE 2

Different levels of probability for optimum date of sowing

Week	Assured Yield (t/ha) at different levels of probability			Average Yield (t/ha)
	60%	75%	90%	
Week 1 (1 -7 Nov)	4.528	3.233	3.156	4.455
Week 2 (8 -14 Nov)	4.433	3.493	3.260	4.435
Week 3 (15 -21 Nov)	4.309	3.515	3.143	4.369

It can be seen from the table that optimum week of sowing in 2004-05 and 2005-06 were 14 to 20 November and 19 to 24 November, respectively and so on as simulated by Aquacrop model for different years. Apart from the optimum week two additional weeks, *viz.*, the previous and succeeding week of optimum week also have been considered to find out optimum dates at different levels of probability. Thereafter probability analysis was conducted at different levels *e.g.*, 90, 75 and 60% for the above mentioned days in each year of simulations. Probability analysis was carried out following the method as suggested by Doorenbos and Pruitt (1984).

Results of the probability analysis presented in the Table 2 suggests that if wheat crop is sown in the first week of November (week starting from 1stNovember and ending on 7th November) in *Tarai* region than, there would be 60% chances to achieve 4.528 t/ha wheat yield, however assured yield decreased to 3.233 and 3.156 t/ha, at probability level 75 and 90%, respectively. The average wheat yield (on the basis of 10 years simulated yield) sown in the first week of November is reported as 4.455 t/ha. Wheat sown in second week of November produced 4.433, 3.493 and 3.260 t/ha respectively at 60, 75 and 90% probability, while average yield of the week is 4.435 t/ha, which is slightly lower than the average yield of first week. Delayed sowing of the wheat resulted into decreased yield of 4.309, 3.515 and 3.143 t/ha respectively at 60, 75 and 90% probability with normal yield of 4.369 t/ha.

Therefore, on the basis of simulated value of wheat yield by Aquacrop model, it can be clearly inferred that wheat can be grown successfully with maximum productivity when sown on dates ranging from 1st November to 7th November. Wheat sown during first week of November not only produces maximum average productivity (4.455 t/ha) but also there will be more than 6 cases out of 10 when farmer will get assured wheat productivity of 4.528 t/ha. Further if farmers fail to sow the crop in first week of November, he can still sow crop in second week of November with reasonably high average yield of 4.435 t/ha and assured yield of4.433 t/ha at 60% probability. However, it is not recommended to sow the crop in third week of November as average and assured yield both are low. Crop sowing dates may be chosen, more so to ensure favourable weather conditions during later stages of crop like flowering and post flowering than ensuring optimal conditions in the early growth stages. The optimal sowing time for wheat is a quite uncertain in *Tarai* region as the harvesting of previous crop of rice often get delayed due to relatively cooler temperature, which causes delay in sowing of wheat crop. Sowing too late of wheat crop causes chance of increases hot and dry conditions during grain filling resulting into forced maturity. Another factor which favours the late sowing of the wheat crop is frequently affected by bad weather condition during late April and early May, which coincide with maturity of late sown wheat crop (Nain, 2016).Timely seeding helps hasten establishing and development by full use of the growing period. It can be now realized if wheat is sown with the help of power mulcher cum seeder (ex superseeder), which can sow wheat immediately (even same day) after harvesting of the rice crop.

4. Conclusions

The validated AquaCrop model was applied to select optimum sowing dates. Aquacrop model initially simulated the optimum sowing week based on sowing dates produced higher yield (Mhizha, 2013). Then optimum sowing dates were identified through yield categorization. After critically analysing the data, it has been revealed that, at "60% level of probability" week starting from 1st November to 7th November is optimum for *Tarai* region of Uttarakhand. It should be sown up to second week of November. In no case sowing of wheat should be delayed to third week of November and beyond due to poor assured and average yield and also increasing chances of crop witnessing bad weather conditions especially storms, intense rainfall and hailstones leading to lodging and poor quality.

Acknowledgement

The authors acknowledge the support received from G. B. Pant University of Agricultural and Technology as well as Head of the Agromet department for guidance while undertaking the study.

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