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# Effect of different mitigation options on growth, productivity and economics of wheat (*Triticum aestivum*)

O KUMAR[1], N JAIN[2]*, K SINGH[3], N RAMAWAT[4], A BHATIA[5] and D K SHARMA[6]

*ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India*

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ABSTRACT

Wheat (*Triticum aestivum* L.) is second most important food grain after rice and is consumed in different forms. The production of wheat in India is currently facing new challenges due to increasing population and adverse impacts of climate change. The production of wheat has increased significantly after the introduction of high yielding varieties. Modern wheat cultivars require adequate amount of nitrogen (N) fertilizer and several irrigations for economical production. The amount and type of nitrogen fertilizers not only affect the production of wheat but also has impact on climate change due to emission of nitrous oxide. A field experiment was conducted in 2016-17 to study the impact of water management (3 and 5 irrigations) and nitrogen fertilizer (urea, neem coated urea (NCU), urea with thiourea, and leaf colour chart (LCC) based N application) on wheat production and profitability. The nitrogen-management practices and irrigation practices significantly influenced the yield parameters, cost of cultivation, net returns and benefit to cost ratio of wheat crop. Grain yield was increased by 15.89% ($p \geq 0.05$) in 5 irrigations compared to 3 irrigations. The grain yield increased by 3.0%, 3.4% and 5.9% in treatments where N was applied using NCU, LCC based N application and urea + thiourea respectively, over urea treatment. Grain yield per kg of N applied was highest in LCC based N application treatment followed by thiourea + urea, NCU and urea N treatments. Highest gross returns was from thiourea treatment however the net returns and B: C ratio were highest in LCC based urea N application due to higher biological yield and saving of 20 kg nitrogen per ha. The study revealed that the economic performance of greenhouse gas mitigation technologies where N was applied based on the plant requirement using leaf colour chart and 5 irrigations was the best followed by application of nitrification inhibitor thiourea with urea and 5 irrigations.

**Key words:** Benefit cost ratio, Irrigation, Neem coated urea, Nitrification inhibitor, Thiourea, Wheat

Wheat (*Triticum aestivum* L.) is the second most important cereal crop after rice in India. Of the total arable land of world one-sixth is under wheat cultivation. India is the second largest producer of wheat with approximately 12% world's wheat production. At present total area under wheat crop is 29.8 million ha (Mha) which is approximately 23% of the total area under food grains (MoA & FW).The production of wheat was only 6.46 million tonnes from 9.75 million ha during 1950-51 contributing 12.7% to the total food grain basket of the country. The production of wheat has observed a significant increase after green revolution from 20.1 Mt in 1969-70 to 101.2 Mt in 2018-19 (MoA&FW).The contribution of wheat to the total food grain production has also increased from 20% in 1969-70 to 35.7% in 2018-19 (MoA& FW).The major wheat producing states are Uttar Pradesh, Punjab, Haryana and Madhya Pradesh. Although India has achieved food self-sufficiency at national level however production of wheat in India is currently facing new challenges due to increasing population and adverse impacts of climate change such as terminal heat and terminal rain. Water scarcity due to depletion of water resources is another big challenge faced in the wheat growing regions of India. Approximately 93% of the total area under wheat crop is irrigated with average water requirement of approximately 45 cm. There is large variation among the states with farmers applying as low as 28 cm of irrigation water in Bihar and 42-45 cm in Punjab and Haryana (Sharma *et al*. 2018). The importance of adequate irrigation for wheat cultivation is evident from the large yields gap between

*Corresponding author email:nivetajain@gmail.com

[1]Ph D Scholar (email:kumaromiari@gmail.com), Amity Institute of Organic Agriculture, Amity University, Noida, Uttar Pradesh and Centre for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi; [2]Principal Scientist (e mail:nivetajain@gmail.com; nivjain@iari.res.in), Centre for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi, 110 012; [3]Director (email:ksingh6@amity.edu), Amity Center for Soil Sciences, Amity University, Noida, Uttar Pradesh; [4]Director (email:nramawat@amity.edu), Amity Institute of Organic Agriculture, Amity University, Noida, Uttar Pradesh; [5]Principal Scientist (email: abensc@gmail.com), [6]Principal Scientist (email:dineshpusa69@gmail.com), Centre for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi 110 012.

irrigated and rain fed crop. Water productivity of wheat is estimated to be in the range of 0.8–1.22 kg $m^{-3}$ (Meena *et al.* 2015, Sharma *et al*. 2018). It is evident that many biotic and abiotic factors may have significant effect on wheat production. Modern wheat cultivars require adequate amount of nitrogen (N) fertilizer and several irrigations for economical production. Irrigation and fertilization at crown root initiation is considered important for the growth and development of wheat. Number of irrigations may vary depending upon the cultivar, soil texture and climate of the region. Increasing the number of irrigations will increase the cost of cultivation. The amount and type of nitrogen fertilizers not only affects the production of wheat but also has impact on climate change due to emission of nitrous oxide. Use of nitrification inhibitors to reduce the emission may further increase the cost of cultivation. Increasing the wheat production while decreasing the cost of cultivation with less emissions is the current challenge for researchers and policy maker all across the world. The present study was conducted with an aim to evaluate the impact irrigation and N fertilizers on wheat production and profitability in the Indo-Gangetic plains of India.

## MATERIALS AND METHODS

*Experimental site and soil*

A field experiment was carried at research farm of ICAR-Indian Agricultural Research Institute, Delhi in *rabi* season (dry season) during 2016-2017. The research farm falls under Indo-Gangetic plains of Northern India situated at $28^0$ 40’ N latitude and $77^0$ 12’ E longitudes. The climatic condition of the experimental site was sub-tropical, semi-arid characterized by dry winter and prolonged hot summer. Annual rainfall is around 750 mm and 80% rainfall occurring during monsoon season (June to September). During the wheat growing period the mean maximum and minimum temperature was 25ºC and 8.9 ºC respectively. The rainfall during the crop growth period was 0.19 mm. The soil of the experimental site was loamy in texture (47% sand, 31% silt and 22% clay) with bulk density of 1.38 g $cm^{-3}$, pH (1:2, soil:water) of 8.0, electrical conductivity of 0.50 dS $m^{-1}$, organic carbon 0.43%, total N 0.4 g $kg^{-1}$, Olsen P and ammonium acetate extractable K contents of 0.007 g $kg^{-1}$and 0.15 g $kg^{-1}$, respectively.

*Treatment details and crop management*

The present experiment included two irrigations, viz. 3 and 5 irrigations with five N treatments, each arranged in a randomized block design with three replications in the plots size of 4 m × 3 m (Table 1). The N fertilizer was applied at the rate of 120 kg N $ha^{-1}$ in three splits in all the treatments (60 kg $ha^{-1}$ as basal, 30 kg $ha^{-1}$ each in two split) except in leaf colour chart (LCC) based application of nitrogen. In LCC treatment 100 kg N $ha^{-1}$ was applied, 40 kg $ha^{-1}$ as basal dose and two splits of 30 kg $ha^{-1}$. For LCC treatment green color of the youngest fully expanded leaf of 10 wheat plants was measured in each replicate plot from CRI stage onwards at every 10 days. When the LCC value of six to seven out of 10 leaves were found below 4, 30 kg N $ha^{-1}$ of urea was applied through top dressing on the same day. Nitrification inhibitor thiourea was applied at the rate of 10% of N after physically mixing with urea. Phosphorus (60 kg $P_2O_5$ $ha^{-1}$) and K (60 kg $K_2O$ $ha^{-1}$) were incorporated into the soil at the time of sowing using single superphosphate (SSP) and muriate of potash (KCl), respectively, in all treatments. Wheat (HD 2967, 100 kg seed $ha^{-1}$) was sown on 6th December 2016 with in rows 20 cm apart. Irrigation water of 5±2 cm each was applied through check-basin. Manual management of weed was done as and when required during the cropping period.

Table 1 Details of the treatments

| Treatment | Nitrogen | Irrigation |
|---|---|---|
| Control | 0 kg N $ha^{-1}$ | 3 |
| Urea | 120 kg N $ha^{-1}$ | |
| NCU | 120 kg N $ha^{-1}$ | |
| Urea (LCC based application) | 100 kg N $ha^{-1}$ | |
| Urea + Thio urea (@10% of urea N) | 120 kg N $ha^{-1}$ | |
| Control | 0 kg N $ha^{-1}$ | 5 |
| Urea | 120 kg N $ha^{-1}$ | |
| NCU | 120 kg N $ha^{-1}$ | |
| Urea(LCC based application) | 100 kg N $ha^{-1}$ | |
| Urea + Thio urea(@10% of urea N) | 120 kg N $ha^{-1}$ | |

*Measurement of growth and yield parameters*

Growth parameters of wheat like plant height, number of tillers $m^{-2}$, number of spikes and spikelets $m^{-2}$ were recorded. Yield parameters like test weight, grain yield and harvest index were recorded at the time of harvest. Crop yields were determined from the total plot area. The grains were separated from the straw, dried, and weighed. Grain and straw moisture was determined immediately after weighing and subsamples were dried in the oven at 65 °C for 48 hr and final dry weight was recorded. Harvest index (HI) was calculated as given below:

Harvest Index (%) = [Grain yield/Straw yield + Grain yield] *100

Partial factor productivity (PFP) was calculated in units of crop yield per unit of N fertilizer applied (Fixen *et al.* 2014) and agronomic efficiency (AE) was calculated in units of yield increase per unit of N applied (Alam *et al.* 2007).

PPF (kg grain $kg^{-1}$ N applied) = (Grain yield / Amount of N applied)

AE (kg grain $kg^{-1}$ N applied) = (Grain yield with N applied - Grain yield with N )/Amount of N applied

*Economic analysis*

After completion of the field experiment on rice, the economic analysis of the treatments were done to identify factors responsible for differences in economic benefit. The operational cost of cultivation was calculated by taking into account the cost of inputs (seed, fertilizers, biocide, diesel and electricity) and the hiring charges of services for various farm operations like land preparation, irrigation, fertilizer application and harvesting. The cost of cultivation was calculated using following formula as given by Fagodia *et al.* (2019):

Total cost of cultivation (₹ ha$^{-1}$) =Input cost [Seed cost + Fertilizer cost + Energy cost (diesel and electricity)] + Cost of hiring services (human and machine)] + miscellaneous cost (@ 10% of total cost)

The cost of all parameters are in ₹ ha$^{-1}$

Cost of energy (₹ ha$^{-1}$) = [(Diesel consumed by tractor (l ha$^{-1}$) × total duration of tractor operation (hrs ha$^{-1}$) × price of diesel (₹ l$^{-1}$)] + [Electricity consumed by electric pump for irrigation (kWhr$^{-1}$) × total duration of pump operation (hr ha$^{-1}$) × electric charge (₹ (kW)$^{-1}$)]

The current market price of all the inputs and hired services during respective season of cultivation were taken into account and derived from market survey. Gross income was the Minimum Support Price offered by the Government of India for wheat in the respective year plus income from selling of residue obtained from market survey. The gross income was determined by the following formula as given by Gupta *et al.* (2016):

Gross income (₹ ha$^{-1}$) = [Total grain yield (kg ha$^{-1}$) × Minimum support price of grain (₹ kg$^{-1}$)] + [Total straw yield (kg ha$^{-1}$) × market price of straw (₹ ha$^{-1}$)]

Net income of the farmers was calculated as the difference between gross income and total cost. Finally benefit to cost ratio was determined by the following formula:

Benefit to cost ratio (B:C)=(Gross income (₹))/(Total cost (₹))

*Statistical analysis*

Data were analyzed by applying the technique of 'analysis of variance (ANOVA)' for Randomized Block Design using SPSS (version 16.0) software. ANOVA with Duncan's Multiple Range Test (DMRT) at 5% level of significance was carried out to test whether the differences between means were statistically significant or not.

## RESULTS AND DISCUSSION

*Growth parameters and yield attributes*

The growth and yield attributes of the wheat crop under different treatments is represented in Table 2. Plant growth parameters such as plant height, tillers per meter square, tillers per plant, and number of spikelets per apike may be affected by irrigation and as well as nitrogen application in wheat crops.

*Effect of irrigation*: No significant effect of irrigation was observed on different growth and yield parameters of wheat crop like plant height, number of tillers, number of spikes m$^{-2}$. However the numbers of spikelets per spike and differed significantly among the two irrigation treatments (Table 2).

Table 2 Effect of irrigation and nitrogen management on growth and yield attributes of wheat

| Management | Plant height (cm) | Tillers (m$^{-2}$) | No. of Spikes (m$^{-2}$) | No. of spikelets spike$^{-1}$ | No. of grains spike$^{-1}$ | Test weight (g) |
|---|---|---|---|---|---|---|
| *Irrigation* | | | | | | |
| 5 Irrigation | 91.1 | 362 | 357 | 42 | 38 | 33.7 |
| 3 Irrigation | 89.9 | 334 | 352 | 37 | 34 | 32.9 |
| SEM (±) | 1.5 | 12 | 7.3 | 0.7 | 0.5 | 0.3 |
| CD (P=0.05) | NS | NS | NS | 1.1 | 1.5 | NS |
| *Nitrogen* | | | | | | |
| No N | 81.0 | 313 | 293 | 28 | 24 | 30.8 |
| Urea N | 93.1 | 341 | 353 | 43 | 38 | 33.6 |
| NCU-N | 92.7 | 362 | 361 | 43 | 40 | 34.8 |
| Urea(LCC based application) | 95.1 | 350 | 376 | 42 | 38 | 34.3 |
| Urea+ Thiourea | 90.8 | 375 | 387 | 44 | 41 | 33.0 |
| SEM (±) | 2.3 | 18.5 | 11.6 | 1.1 | 0.8 | 0.5 |
| CD (P=0.05) | 6.79 | 55 | 34.0 | 3.25 | 2.3 | 1.5 |
| Irrigation × nitrogen | NS | NS | NS | NS | NS | NS |

Plant height, number of tillers, spikes, spikelets and grains per spike were affected by different N treatments. The plant height was lowest in no N treatment (80.97 cm) followed by urea + thiourea (90.75 cm) > NCU (92.7 cm),> urea-N (93.10 cm) and LCC based urea application (95.1 cm). However there was no significant difference in Urea-N, urea + thiourea, LCC based urea and NCU-N treatments. The number of tiller ranged from 313 in control treatment (where no N was applied) to 375 per square meter in urea +thiourea treatment. LCC based application of urea N treatment had higher number of spikelets per square meter in comparison with thiourea treatment. Number of spikes m$^{-2}$ were significantly higher in urea with nitrification inhibitor thiourea treatment compared to urea alone and NCU treatments. Sahu *et al.* (1995) have also reported similar results for soil application of thiourea @ 10 kg ha$^{-1}$. However urea and NCU treatments were statistically at par. Number of grains per spike differed significantly among the N treatments and ranged from 24 to 41. There was no significant impact of water and nitrogen application on test weight of the grains. The test weight varied from 34.17 to 34.91g (Table 2). Shirazi *et al.* (2014) have also reported that irrigation and nitrogen level has significant impact of growth parameters and yield of wheat. The interactive effect of nitrogen and irrigation was non-significant in all the growth parameters and yield attributes.

*Grain and straw yield and harvest index*

The grain yield, straw yield, and harvest index are given in Table 3. The nitrogen-management practices and irrigation practices significantly influenced yields parameters (Table 3).

Grain yield varied from 2162 to 4789 kg ha$^{-1}$ among the N treatments and 3863 to 4475 kg ha$^{-1}$ in different irrigation practices (Table 3).The highest grain yield (4789 kg ha$^{-1}$) was recorded in thiourea + urea-N. There was a yield advantage of 3.0%, 3.4% and 5.9% in treatments where N was applied using NCU, LCC based N application and urea + thiourea respectively over urea treatment. Thiourea contains thiol group and thiols have been reported for enhanced photosynthesis, increased metabolite translocation, increase in grain filling and coordinated regulation of plant's source to sink relationships due to foliar spray of thiourea in different crops like wheat and mustard (Pandey *et al*. 2013; Sharma *et al.* 2015). Sahu *et al*. (1995) have reported 17.54% and 1.6% increase in grain yield by soil application of 10 kg and 20 kg thiourea respectively. Grain yield was statistically at par in treatments NCU and LCC based N application, although N applied in LCC treatment was reduced by 20 kg compared to other N treatments. Application of 10% N through nitrification inhibitor thiourea increased the yield by 2.8% compared to NCU-N (significant $p \geq 0.05$) and 2.3% compared to LCC based urea –N application. Grain yield per kg of N applied was highest in LCC treatment followed by thiourea + urea, NCU and urea N treatments. Similar trends were observed in straw yield. The increase in grain and straw yields might be due to balanced nutrients supplied as per the need of the crop during the crop growth period resulting in increase in yield attributing characters which ultimately increased the economic yield in LCC based N application. Giday (2019) have also reported significant effect ($P \geq 0.01$) of the application of super granules urea and rates of N fertilizer on wheat grain yield and straw yield in Ethiopia. The harvest index was 39% in 3 irrigation and 40.4% in 5 irrigations (Table 3). In different N treatments HI varied from 37.9% to 41.3%. HI was maximum in thiourea treatment followed by NCU, LCC and urea treatments. The interactive effect of nitrogen and irrigation was found to be highly significant ($P \geq 0.05$) for all the yield parameters. Both partial factor productivity and agronomic efficiency in terms of applied N was significantly affected by irrigation and different N fertilizers ($P \geq 0.05$). Application of LCC based N fertilizers and nitrification inhibitor thiourea with urea increased the nitrogen efficiency by the crop. PFP-N was maximum with 5 irrigations and LCC based N application followed by 3 irrigations with LCC based N application and 5 irrigations with urea + thiourea based N application. However the AE-N maximum with 5 irrigations and LCC based N application followed by 5 irrigations with urea + thiourea based N application and 3 irrigations with LCC based N application. Wang *et al.* (2010) and Kakraliya *et al.* (2017) have also reported enhanced nutrient use efficiency by balanced use of nutrients.

*Economics*

The variations among the cost of cultivation, net returns and benefit cost ratio of wheat crop under different irrigations and nitrogen treatments is given in Table 5. The total cost of cultivation among different irrigation regimes ranged from ₹ 42301 to ₹ 44906 per ha. The net returns varied between ₹ 31654 and ₹ 39430 per ha and the benefit to cost ratio was between 1.7 and 1.9 (Table 5). The gross and net returns in 5 irrigations increased by14.3% and 26.4% in 5 irrigations compared to 3 irrigations. The B:C was also higher by 7.3% in treatment where 5 irrigations

Table 3 Effect of irrigation and nitrogen management on the yield and harvest index of wheat

| Management | Grain yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Biological yield (kg ha$^{-1}$) | Harvest Index (%) |
|---|---|---|---|---|
| *Irrigation* | | | | |
| 5 irrigations | 4475 | 6531.6 | 10986.9 | 40.4 |
| 3 irrigations | 3863 | 5987.4 | 9840.3 | 39.0 |
| SEM (±) | 28.4 | 40.2 | 51.8 | 0.2 |
| CD (p=0.05) | 83.9 | 118.6 | 152.7 | 0.7 |
| *Nitrogen* | | | | |
| No N | 2162 | 3538.0 | 5700.0 | 37.9 |
| Urea N | 4531 | 6991.8 | 11522.5 | 39.3 |
| NCU-N | 4669 | 6747.7 | 11416.3 | 40.9 |
| Urea (LCC based application) | 4685 | 7241.2 | 11925.7 | 39.3 |
| Urea+ Thiourea | 4798 | 6778.8 | 11577.5 | 41.2 |
| SEM (±) | 45 | 63.6 | 81.9 | 0.4 |
| CD (p=0.05) | 132.6 | 187.6 | 241.5 | 1.1 |
| *Irrigation × nitrogen* | | | | |
| SEM (±) | 74.4 | 110.1 | 141.8 | 0.7 |
| CD (p=0.05) | 219.4 | 324.9 | 418.2 | 1.9 |

Table 4 Effect of irrigation and nitrogen management on the partial factor productivity (PFP-N) and agronomic efficiency (AE-N) of wheat

| Management | PFP-N (kg kg$^{-1}$) | AE-N (kg kg$^{-1}$) |
|---|---|---|
| *Irrigation* | | |
| 5 irrigations | 43.9 | 23.7 |
| 3 irrigations | 37.9 | 20.3 |
| SEM (±) | 0.4 | 0.4 |
| CD (p=0.05) | 0.9 | 0.9 |
| *Nitrogen* | | |
| Urea N | 37.8 | 19.7 |
| NCU-N | 38.9 | 20.9 |
| Urea (LCC based application) | 46.8 | 25.2 |
| Urea + Thiourea | 40.0 | 22.0 |
| SEM (±) | 0.4 | 0.4 |
| CD (p=0.05) | 1.3 | 1.3 |
| *Irrigation × nitrogen* | | |
| SEM (±) | 0.7 | 0.7 |
| CD (p=0.05) | NS | NS |

Table 5 Effect of different management practices on net returns and cost benefit ratio

| Management | Cost of cultivation (₹ $ha^{-1}$) | Gross returns (₹ $ha^{-1}$) | Net returns (₹ $ha^{-1}$) | B:C |
|---|---|---|---|---|
| *Irrigation* | | | | |
| 5 irrigations | 44906 | 84273 | 39430 | 1.87 |
| 3 irrigations | 42301 | 73725 | 31654 | 1.74 |
| Nitrogen | | | | |
| No N | 41150 | 41816 | 666 | 1.02 |
| Urea N | 43689 | 86574 | 42885 | 1.98 |
| NOCU-N | 43950 | 87090 | 43140 | 1.98 |
| Urea (LCC based application) | 43767 | 89542 | 45775 | 2.04 |
| Urea+ Thiourea | 44728 | 89974 | 45246 | 2.01 |

were applied. The total cost of cultivation and net returns in different N treatments ranged between ₹ 41150 $ha^{-1}$ and ₹ 44728 $ha^{-1}$ and ₹ 666 $ha^{-1}$and ₹ 45775 $ha^{-1}$ respectively (Table 4). Highest gross returns was from thiourea treatment however the net returns, and B:C were highest in LCC based urea N application due to higher biological yield and saving of 20 kg nitrogen. Benefit to cost ratio was same in urea and NCU treatment. Although the yield in NCU treatment was more than urea but the cost of NCU fertilizer was also more than urea. The benefit to cost ratio was significantly affected by nitrogen fertilizer as well irrigation practices.

*Conclusions*

The nitrogen application using different sources of N fertilizer had significant ($P < 0.05$) effect on straw and grain yield of wheat. The study revealed that the economic performance of leaf colour chart based N application with 5 irrigations was best followed by application of nitrification inhibitor thiourea with urea as compared to other nitrogen treatments. There was a saving of 20 kg N per ha with leaf colour chart based N application. The excess of applied N use may contribute to environmental degradation through nitrification, denitrification, runoff, volatilization, and leaching, indicating that the management practices can play a significant role in achieving the goal of sustainable wheat production in a changing environment. Therefore, demand driven N application using slow-release fertilizers or nitrification/urease can be used to increase fertilizer use efficiency with less potential losses to the environment.

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## REFERENCES


Agricultural Statistics at a Glance. 2018. Ministry of Agriculture and Farmers Welfare (MoA& FW).

Alam M M, Ladha J K, Foyjunnessa, Rahman Z, Khan S R, Rashid H, Khan A H, and Buresh R J. 2006. Nutrient management for increased productivity of rice-wheat cropping system in Bangladesh. *Field Crops Research,* **96**: 374–386.

FAO. 2019. http://www.fao.org/faostat/en/#data

Fixen P, Brentrup F, Bruulsema T, Garcia F, Norton R. and Zingore S. 2014. Nutrient/fertilizer use efficiency: measurement, current situation and trends. Chapter 1. Nutrient/Fertilizer Use Efficiency: Measurement, Current Situation and Trends, in Managing Water and Fertilizer for Sustainable Agricultural Intensification, IFA, IWMI, IPNI and IPI. (www.fertilizer.org/ library publications@fertilizer.org)

Giday O. 2019. Effect of type and rate of urea fertilizers on nitrogen use efficiencies and yield of wheat (*Triticum aestivum*) in Northern Ethiopia. *Cogent Environmental Science* 5:1, 1655980.

Gupta D K, Bhatia A, Das T K, Singh P, Kumar A, Jain N, Pathak H. 2016. Economic analysis of different greenhouse gas mitigation technologies in rice wheat cropping system of the Indo-Gangetic Plains. *Current Science* 110 (5): 867.

Kakraliya S K, Jat R D, Kumar S, Choudhary K K, Prakash J and Singh L K. 2017. Integrated nutrient management for improving, fertilizer use efficiency, soil biodiversity and productivity of wheat in irrigated rice wheat cropping system in Indo-Gangetic Plains of India. *International Journal of Current Microbiology and Applied Sciences* **6**:152-163.

Meena R P, Tripathi S, Chander S, Chhokar R and Sharma R. 2015. Seed priming in moisture-stress conditions to improve growth and yield of wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **60**:99–103.

Pandey M, Srivastava A K, D’Souza S F and Suprasanna P. 2013. Thiourea, a ROS scavenger, regulates source-to-sink relationship for enhanced crop yield and oil content in *Brassica juncea* (L.). *PloS One* **8(9)**: e73921.

R K Fagodiya, H Pathak, A Bhatia, N Jain, D Gupta. 2019. Nitrous oxide emission and cost of mitigation in maize-wheat system of the Indo-Gangetic Plains. Indian *J of Agri. Sci*, **90**(1): 69–74.

Sahu M P and Singh D. 1995. Role of thiourea in improving productivity of wheat (*Triticum aestivum* L.). *Journal of Plant Growth Regulation* **14**: 169–173.

Sharma K M, Asarey R and Verma H. 2015. Response of wheat (*Triticum aestivum* L.) to the foliar applied brassino steroid and thiourea with recommended fertilization practice on farmer’s fields. *Plant Archives* **15**: 729-732.

Shiraz, S M, Yusop Z, Zardari N H, and Ismail Z. 2014. Effect of irrigation regimes and nitrogen levels on the growth and yield of wheat. *Advances in Agriculture*, https://doi.org/10.1155/2014/250874

Singh G D, Vyas A K and Dhar S. 2015. Productivity and profitability of wheat (*Triticum aestivum*)-based cropping systems under different nutrient-management practices. *Indian Journal of Agronomy* **60**: 52-56.

Wang Y C, Wang E L, Wang D L, Huang S M, Ma Y B, Smith C J, and Wang L G. 2010. Crop productivity and nutrient use efficiency as affected by long-term fertilization in North China Plain. *Nutrient Cycling in Agroecosystems* **86**: 105-119.