Impacts of irrigation frequency and nitrogen rate on productivity, quality, nutrient uptake and nutrient use efficiencies of late sown wheat (*Triticum aestivum* L.)

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**ABSTRACT**

An experiment was conducted at CCS Haryana Agricultural University, Hisar during *rabi* 2010-11 and 2011-12, consisting of three irrigation frequencies viz. one irrigation at CRI, two irrigations at CRI and heading and four irrigations at CRI, late tillering, heading and milking in main plots and five nitrogen levels (0, 50, 100, 150 and 200 kg N/ha) in sub-plots in strip plot design with four replications. Grain yield and NUE increased significantly with increased irrigation levels. Increase irrigation frequency increased the N (33.4 and 31.3 %), P (42.2 and 42.3 %) and K (26.7 and 25.1 %) uptake over one irrigation during 2010-11 and N (16.0 and 15.9 %), P (19.4 and 20.7 %) and K (11.2 and 13.5 %) during 2011-12. Increased nitrogen dose increased the protein content, hectolitre weight, sedimentation value and grain yield over control. Maximum and minimum nutrient uptake was recorded with 200 and 0 kg N/ha.

**Key words:** Nutrient Use Efficiency, Productivity, Quality, Wheat.

**INTRODUCTION**

Wheat (*Triticum aestivum* L.) is the second most important staple food crop of the world. During 2016-17 area, production and productivity of wheat in India is 30.59 mha, 98.3 mt and 3216 kg/ha (Anonymous, 2016-17). Its area and productivity is increasing rapidly adopting across the globe, due to its wider adaptability sustainability under divers agro climatic conditions (Kumar *et al*., 2014). Non availability of pre-sowing irrigation, untimely rains, delayed field conditions in waterlogged areas and American cotton-wheat, Basmati rice-wheat, potato-wheat and sugarcane-wheat rotations, where the sowing of the wheat gets delayed owing to late harvest of preceding crop as compulsion and not choice of the farmers (Joshi *et al*., 2007). Among production factors, irrigation frequency and nitrogen rates are the most crucial factors deciding its productivity. A significant irrigation effect was observed on grain yield, grain numbers and straw yield. The highest levels were achieved with a high irrigation supply (Wang *et al*., 2012). There was significant positive interaction between irrigation and nitrogen levels with respect to grain yield, water productivity and nitrogen use efficiency of wheat (Pradhan *et al*., 2013). Increased yield with more N application, fact that N being an important constituents of nucleotides, proteins, chlorophyll and enzymes, involves in various metabolic processes which have direct impact on vegetative and reproductive phases of plants (Chaturvedi, 2006). Additional irrigation was profitable only when accompanied by additional nitrogen. Synergistic interaction between irrigation and nitrogen levels have also been reported by Shirazi *et al*., (2014). Nitrogen dose increase grain quality of wheat by significant increase in protein content, hectolitre weight, sedimentation value in nitrogen applied treatment over control. This increase in protein content with increase in dose of nitrogen because nitrogen being the constituent of different amino acids which form different types of protein in wheat grain. Hectolitre weight, sedimentation value were also increased with nitrogen nutrition, which has increased the density of grain through the formation of different biochemicals in comparison to control (Ramesh *et al*., 2008 and Rani *et al*., 2009). Higher uptake of NPK in grain and straw under higher dose of N, which encouraged the crop growth and finally higher grain and biomass yield (Singh *et al*., 2011 and Rawal and Kuligod, 2014). Keeping these points in mind, the objective of the study was to investigate the impact of irrigation frequency and nitrogen rate on yield, quality, uptake and nutrient use efficiency of late sown wheat.

**MATERIALS AND METHODS**

To study the impact of irrigation frequency and nitrogen rate on yield, quality, uptake and nutrient use efficiency of late sown wheat an experiment was conducted during 2010-11 and 2011-12 at CCS Haryana Agricultural University, Hisar (India) located in Indo-Gangetic plains of North-West India with a latitude of 29°10’ North and longitude of 75°46’ East at 215.2 meters above mean sea level. The soil of the field was sandy loam, having 0.39%...
OC and pH 7.95. It was low in available N (156.1 kg/ha), medium in available P (10.5 kg/ha) and high in available K (306.4 kg/ha). The experiment consisting of three irrigation frequencies viz. one irrigation at CRI, two irrigations at CRI and heading and four irrigations at CRI, late tillering, heading and milking in main plots and five nitrogen doses viz. control i.e. 0 kg N/ha, 50 kg N/ha, 100 kg N/ha, recommended dose of nitrogen i.e. 150 kg N/ha and 200 kg N/ha in sub-plots was laid out in strip plot design with four replications. Nitrogen was applied in the form of urea during both the year. Nitrogen was applied in two splits: half of the nitrogen was applied as basal and half as top dressed after 1st irrigation. The recommended dose of phosphorus (60 Kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1}) was applied through di-ammonium phosphate (DAP) at time of sowing while in control treatment phosphorous was applied in the form of single super phosphate (SSP). Wheat cv. WH 1021 was sown with the help of seed drill in rows 18 cm apart at the rate of 125 kg/ha. Crop was sown on 18\textsuperscript{th} December during both the years of the experimentation. Irrigation was applied in the field as per treatments. The weeds were removed by long tine hoe at 40 days and later by hand pulling. Nesslers reagent method were used (Linder, 1944) for nitrogen estimation, Vanadiumolybdo-phosphoric acid yellow colour method (Koenig and Johnson, 1942) for phosphorus and Flame photometer method (Richards, 1954) for potassium contents. Uptake of these nutrients was calculated as kilogram per hectare by multiplying the contents with grain and straw yields. Protein content in grain was calculated by multiplying the percentage of nitrogen in grains with 6.25. Hectolitre weight was measured with the hectoliter weight equipment having standard volume of container/beaker and weight of grain was taken on electronic balance. Sedimentation value was worked by SDS Sedimentation test (Axford et al., 1979), N use efficiency (NUE) was worked out as product of physiological efficiency and nitrogen recovery. Data was analysed statistically with OPSTAT software.

**RESULTS AND DISCUSSION**

Impacts of irrigation frequency and nitrogen rate was studied on yield, quality, nutrient uptake and nutrient use efficiencies of late sown wheat during 2010-11 and 2011-12, respectively.

**Effect on yield:** The significant increase in grain, straw and biological yield with the increase in irrigation frequency (Table 1). The increase in irrigation number from one to two, two to four and one to four irrigations increased the grain yield of wheat by about 25.1, 20.4 and 50.6 % during 2010-11 and 21.0, 21.9 and 47.5 % during 2011-12, respectively. The stronger source is required for the stronger sink. The higher biological yield was found significantly associated with the higher grain yield (r = 0.99). This clearly shows that the biological yield increased by any input or management practice will automatically increase the grain yield of wheat. The grain yield of wheat can also be estimated through biological yield with the regression equation (grain yield = 860.09 + 0.489 biological yield, \(r^2 = 0.98\)). Similarly, straw yield being the constituent of biological yield have very high association (r = 0.99). The regression equation between biological yield and straw yield clearly indicates that the biological yield increased with double the rate than straw yield (biological yield = -1519.7 + 1.925 straw yield, \(r^2 = 0.98\)). The straw and biological yield of wheat increased significantly with increased irrigation level. Significantly higher yield in four irrigation crop than two and one irrigation might be due to more availability of water and nutrients in four irrigations at the time of growth and development than one and two irrigations. The higher photosynthetic rate due to higher plant water status at reproductive phase helped in proper filling of grain cavity due to continuous supply of photosynthates in desired amount. These results corroborate the finding of Fang et al. (2006) and Markovic (2014). Interaction effect of irrigation and nitrogen are shown in Table 2. During 2010-11, at one and two irrigations levels wheat yield increased significantly upto 100 kg N/ha. However, with four irrigations levels wheat grain yield increased significantly upto 150 kg N/ha. The increase in irrigation frequency from one to four increased the grain yield significantly in all doses of nitrogen during 2010-11. During 2011-12 with increased dose of nitrogen also increased the grain yield in all the irrigation levels. At all

### Table 1: Effect of irrigation frequency and nitrogen rate on yield of late sown wheat

| Treatments | Grain yield (kg ha\textsuperscript{-1}) | Pooled | Straw yield (kg ha\textsuperscript{-1}) | Biological yield (kg ha\textsuperscript{-1}) | Harvest Index (%) |
|------------|-----------------------------------|--------|-----------------------------------|---------------------------------|-----------------|
|            | 2010-11 | 2011-12 | 2010-11 | 2011-12 | 2010-11 | 2011-12 | 2010-11 | 2011-12 | 2010-11 | 2011-12 |
| Irrigation frequency |  |  |  |  |  |  |  |  |  |  |
| 1 Irrigation | 2544 | 2704 | 2624 | 4550 | 4872 | 7094 | 7575 | 35.6 | 35.3 |
| 2 Irrigations | 3183 | 3272 | 3228 | 5054 | 5233 | 8238 | 8505 | 38.3 | 38.2 |
| 4 Irrigations | 3832 | 3989 | 3911 | 5470 | 5774 | 9303 | 9763 | 40.9 | 40.6 |
| CD at 5% | 190 | 183 | 136 | 234 | 359 | 418 | 434 | 0.5 | 0.6 |
| Nitrogen rate |  |  |  |  |  |  |  |  |  |  |
| 0 kg N/ha | 1932 | 2026 | 1979 | 3495 | 3708 | 5427 | 5734 | 35.3 | 35.0 |
| 50 kg N/ha | 2946 | 3064 | 3005 | 4828 | 5083 | 7774 | 8147 | 37.7 | 37.4 |
| 100 kg N/ha | 3474 | 3623 | 3549 | 5403 | 5695 | 8878 | 9318 | 38.9 | 38.8 |
| 150 kg N/ha | 3737 | 3893 | 3815 | 5607 | 5883 | 9344 | 9776 | 39.8 | 39.6 |
| 200 kg N/ha | 3843 | 4002 | 3922 | 5791 | 6095 | 9634 | 10097 | 39.7 | 39.4 |
| CD at 5% | 156 | 137 | 120 | 342 | 302 | 483 | 354 | 0.8 | 0.6 |
irrigations levels wheat yield increased significantly up to 150 kg N/ha. The increase in irrigation frequency from one to four increased the grain yield significantly in all doses of nitrogen. The grain yield at 150 and 200 kg N/ha were at par at all the levels of irrigations.

Grain yield was significantly increasing up to 150 kg N/ha (Table 1). The significantly higher grain (98.9 and 97.5 %), straw (65.7 and 64.4 %) and biological yield (77.5 and 76.1 %) along with harvest index (12.5 and 12.6 %) in 200 kg N/ha over control because of more availability of nutrients for their growth and development of better yield attributes and yield. The poor nutrition in control affected the grain yield more than biological yield which ultimately resulted in significant reduction in harvest index. Harvest index is the parameter dependent on grain yield \( r = 0.94^{**} \) and biological yield \( r = 0.89^{**} \). This shows that harvest index was more associated with grain yield than biological yield. The harvest index can also be computed from the grain yield with regression equation \( GY = -8520.9 + 308.52 HI \), \( r^2 = 0.92 \). The significantly higher yield in 200 kg N/ha over control might be due to more NPK uptake than control. The increased uptake of the nutrients was due to added supply of nutrient and well developed root-system resulting in better absorption of water and nutrients. These results are in consonance with the findings of Chaturvedi (2006). Increased yield with more N application may be attributed to the fact that this nutrient being important constituents of nucleotides, proteins, chlorophyll and enzymes, involves in various metabolic processes which have direct impact on vegetative and reproductive phases of plants. These findings confirm those of Chaturvedi, (2006).

### Table 2: Interaction effect of irrigation levels and nitrogen doses on grain yield of late sown wheat

| Treatments | 2010-11 | 2011-12 |
|------------|---------|---------|
|            | 1 Irrigation | 2 Irrigations | 3 Irrigations | 4 Irrigations | Mean | 1 Irrigation | 2 Irrigations | 3 Irrigations | 4 Irrigations | Mean |
| 0 kg N/ha  | 1415     | 1947     | 2435     | 1932     | 1498     | 2050     | 2531     | 2026 |
| 50 kg N/ha | 2344     | 2955     | 3540     | 2946     | 2491     | 3035     | 3665     | 3064 |
| 100 kg N/ha| 2801     | 3472     | 4150     | 3474     | 2984     | 3564     | 4321     | 3623 |
| 150 kg N/ha| 3051     | 3720     | 4441     | 3737     | 3240     | 3803     | 4635     | 3893 |
| 200 kg N/ha| 3110     | 3823     | 4596     | 3843     | 3305     | 3910     | 4791     | 4002 |
| Mean       | 2544     | 3183     | 3832     | 3872     | 3187     | 3704     | 3989     | 3322 |

### Effect on grain quality: The grain quality in terms of protein content and sedimentation value were not affected by irrigation levels except hectoliter weight (Table 3). The significant increase in hectoliter weight in two and four irrigations than one irrigation may be because of more availability of water and nutrients in two and four irrigations at the time of growth and development than one irrigation. The higher photosynthetic rate due to higher plant water status at reproductive phase helped in proper filling of grain cavity due to continuous supply of photosynthates in desired amount. These results corroborate with the findings of Fang et al. (2006) and Markovic (2014). The increased nitrogen dose increased the grain quality of wheat by significant increase in protein content, hectolitre weight, sedimentation value in nitrogen applied treatment over control. This increase in protein content with increase in dose of nitrogen because nitrogen being the constituent of different amino acids which form different types of protein in wheat grain. Hectolitre weight, sedimentation value were also increased with nitrogen nutrition, which has increased the density of grain through the formation of different biochemicals in comparison to control. Similar results have been reported by Kaur et al. (2006), Ramesh et al. (2008) and Rani et al. (2009).

### Effect on NPK content and uptake: The irrigation frequency increased the NPK uptake by the crop with increase in irrigation frequency during both the years (Table 4, 5 and 6). The nitrogen and phosphorous uptake was more through the grain (72.8 % of total N and 68.0 % of total P) than straw and potash was more through the straw (83.2 % of total) than grain. The higher N and P uptake in grain

### Table 3: Effect of irrigation frequency and nitrogen rate on quality parameters of late sown wheat

| Treatments | Protein (%) | Hectolitre weight (g) | Sedimentation value (ml) |
|------------|-------------|-----------------------|-------------------------|
|            | 2010-11 | 2011-12 | 2010-11 | 2011-12 | 2010-11 | 2011-12 |
| Irrigation frequency |
| 1 Irrigation | 11.8 | 11.9 | 73.1 | 74.1 | 33.4 | 34.5 |
| 2 Irrigations | 11.2 | 11.4 | 75.4 | 75.7 | 33.4 | 34.8 |
| 4 Irrigations | 11.1 | 11.3 | 76.7 | 76.1 | 35.6 | 35.7 |
| CD at 5% | NS | NS | 2.1 | 1.5 | NS | NS |
| Nitrogen rate |
| 0 kg N/ha | 10.3 | 10.4 | 72.7 | 73.5 | 30.4 | 31.2 |
| 50 kg N/ha | 11.2 | 11.3 | 74.2 | 74.9 | 32.2 | 33.7 |
| 100 kg N/ha | 11.6 | 11.8 | 75.1 | 75.5 | 34.2 | 35.7 |
| 150 kg N/ha | 11.9 | 12.0 | 76.6 | 76.1 | 36.0 | 37.1 |
| 200 kg N/ha | 12.0 | 12.2 | 76.8 | 76.5 | 36.2 | 37.4 |
| CD at 5% | 0.6 | 0.5 | 1.6 | 1.6 | 3.1 | 2.5 |
because of its chemical composition because of higher amino acid and protein content in grain require more N and P, whereas, higher K content in straw is because of its higher content is required for providing strength to stem by forming cellulose, lignin and pectin. The higher NPK uptake was mainly because of higher grain and straw yield (Table 1) in four irrigations followed by two irrigations compared to one irrigation during both the years. This fact can also be fortified with highly significant positive association between biological yield with N uptake ($r = 0.99$), P uptake ($r = 0.99$) and K uptake ($r = 0.99$). Similar highly significant relationship between grain yield with N uptake ($r = 0.97$),
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Table 7: Effect of irrigation frequency and nitrogen rate on agronomical, physiological, apparent recovery and nutrient use efficiency of wheat

| Treatments | Agronomical Efficiency (kg/kg) | Physiological Efficiency (kg/kg) | Apparent Recovery Efficiency (%) | Nitrogen Use Efficiency (kg/kg) |
|------------|-------------------------------|---------------------------------|---------------------------------|--------------------------------|
|            | 2010-11                        | 2011-12                        | 2010-11                        | 2011-12                        | 2010-11                        | 2011-12                        |
| Irrigation frequency |                                |                                |                                |                                |                                |                                |
| 1 Irrigation | 12.9                         | 13.8                          | 83.9                         | 83.2                          | 38.5                         | 41.3                          | 27.7                         | 29.4                          |
| 2 Irrigations | 14.1                         | 13.9                          | 81.3                         | 79.3                          | 38.9                         | 40.2                          | 34.4                         | 35.3                          |
| 4 Irrigations | 15.9                         | 16.5                          | 75.8                         | 76.9                          | 42.6                         | 44.8                          | 41.2                         | 42.8                          |
| CD at 5%    | NS                           | NS                            | NS                           | 5.8                          | 4.1                          | NS                           | NS                           | 2.7                          | 2.3                          |
| Nitrogen rate |                                |                                |                                |                                |                                |                                |                                |                                |
| 50 kg N/ha  | 20.3                         | 20.7                          | 85.7                         | 84.9                          | 55.9                         | 55.2                          | 58.9                         | 61.3                          |
| 100 kg N/ha | 15.4                         | 16.0                          | 82.5                         | 80.7                          | 45.7                         | 45.2                          | 34.7                         | 36.2                          |
| 150 kg N/ha | 12.0                         | 12.4                          | 76.6                         | 76.5                          | 34.0                         | 35.4                          | 24.9                         | 25.9                          |
| 200 kg N/ha | 9.5                          | 9.9                           | 76.5                         | 77.0                          | 27.4                         | 38.5                          | 19.2                         | 20.0                          |
| CD at 5%    | 2.1                          | 1.2                           | 4.3                          | 5.5                          | 10.2                         | 6.2                           | 1.9                          | 1.4                          |

The increased NPK uptake with increasing nitrogen dose during both the years. The increased level of nitrogen dose increased the NPK uptake in grain and straw but the uptake of N and P was increased with increase in nitrogen content in grain and straw significantly over control during both the years. The higher uptake of NPK in grain and straw under higher dose of N was because of more availability of these nutrients, which encouraged the crop growth and finally higher grain and biomass yield (Table 1). The nutrient status of the plant tissue being the genetic character affected less by the environment but, higher growth require higher uptake. However the P and K uptake through grain and straw was due to variation in grain and straw yield recorded under different dose of N as the P and K content in grain and straw was statistically at par in all the treatments during both the years. Similar result have been reported by Rani et al. (2009), Singh et al. (2011) and Rawal and Kulligod (2014).

Effect on nutrient use efficiency: The agronomical efficiency, physiological efficiency, apparent recovery and nutrient efficiency were more during 2011-12 than 2010-11. This was mainly because of grain yield, biological yield and higher nitrogen uptake during 2011-12 than 2010-11 (Table 7). The increase in irrigation level increased the agronomical efficiency, apparent recovery and nutrient use efficiency but physiological efficiency declined with increase in irrigation frequency, may be because of more nutrient uptake and more biological yield in control i.e. 0 kg N/ha. While the agronomical efficiency and apparent recovery was increased with increase in irrigation frequency due to higher increase in grain yield and higher uptake with the application of nitrogen during both the years. The maximum agronomical efficiency, physiological efficiency, apparent recovery and nutrient use efficiency was recorded in control treatment i.e. 0 kg N/ha, the highest efficiency in control might be due to more efficient utilization of nitrogen than all other treatment. This higher efficiency was mainly because of more uptake of nutrient in this treatment relative to higher doses of the same source (Table 4, 5 and 6). The increase in nitrogen dose decreased the agronomical efficiency, physiological efficiency, apparent recovery and nutrient use efficiency may be because of comparatively low uptake and low grain yield and biological yield this fact can be explained by law of diminishing return. Similar results have been reported by Tedone et al. (2014).

CONCLUSION

The grain yield with four irrigations (3832 and 3989 kg/ha) increased by 50.6 and 47.5% over one irrigation and 20.4 and 21.9% over two irrigation during 2010-11 and 2011-12, respectively. The increase in irrigation frequency increased the N (33.4 and 31.3 %), P (42.2 and 42.3 %) and K (26.7 and 25.1 %) over one irrigation and N (16.0 and 15.9 %), P (19.4 and 20.7 %) and K (11.2 and 13.5 %) over two irrigation in four irrigation treatment during two years of study, respectively. The NUE also increased by 48.7 and 45.6 % over one and 19.8 and 21.2 % over two in four irrigation treatment during both the year of experimentation, respectively. Nitrogen application responded yields significantly upto 150 kg N/ha. The maximum total N (100.1 and 105.1 kg/ha), P (10 and 10.4 kg/ha) and K (93.9 and 99.4 kg/ha) uptake was recorded with the application of 200 kg N/ha during 2010-11 and 2011-12, respectively and decreased with decreasing dose of nitrogen. Increased nitrogen dose increased the grain quality of wheat by significant increase in protein content, hectolitre weight, sedimentation value in nitrogen applied treatment over control. Thus, it may be concluded that the management of nitrogen and irrigation plays a significant role in optimizing wheat production.
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