



## Performance of wheat (*Triticum aestivum*) under different irrigation schedules and sowing methods

L K IDNANI<sup>1</sup> and ASHOK KUMAR<sup>2</sup>

Indian Agricultural Research Institute, Pusa, New Delhi 110 012

Received: 3 August 2012; Revised accepted: 3 July 2012

### ABSTRACT

A field experiment was conducted during *rabi* season of 2007–08 and 2008–09 at IARI, New Delhi, to assess the effects of irrigation schedules and methods of sowing on productivity, water use, economics, soil physical properties and nutrient uptake of wheat (*Triticum aestivum* L. emend. Fiori & Paol) on sandy loam soil. Five irrigation schedules (I<sub>1</sub>, Irrigation at CRI, I<sub>2</sub>, CRI + 200 mm CPE; I<sub>3</sub>, CRI + 150 mm CPE; I<sub>4</sub>, CRI + 100 mm CPE; and I<sub>5</sub>, CRI + 50 mm CPE) were allotted in horizontal strips and three sowing methods (M<sub>1</sub>, Conventional, M<sub>2</sub>, FIRBS and M<sub>3</sub>, side sowing on ridges) were allotted in vertical strips in strip plot design replicated thrice. The FIRBS planting and irrigation at CRI stage + 100 mm CPE registered significantly highest grain yield, straw yield, harvest index, net return, benefit: cost ratio, cumulative infiltration, N, P and K uptake.

**Key words:** Economics, Irrigation schedules, Planting methods, Wheat, Yield, Yield attributes

Wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is very important and remunerative *rabi* crop of North India. It is the second most important cereal crop after rice, grown under diverse agro-climatic conditions on 28 m ha area in India with a production of 84 m tonnes (Economic Survey, 2010-11). The improvements in irrigation efficiencies are possible both at the project level (storage and conveyance efficiencies) and the field application level (by using improved irrigation methods and proper irrigation scheduling). Most of the area in the country is irrigated by surface application methods such as check basin, border strip and furrow irrigation. The selection of a particular method depends upon the topography, soil type, crop, stream size, economics and management aspects. Proper selection of an irrigation method for a particular crop is very important to achieve higher application efficiency. The irrigation efficiency of the border system has been found to be only 30-40% as compared to attainable level of 60-70%. The reasons for the low efficiency are important matching of the hydraulic parameters such as stream size, field slope, plot size with respect to soil and crop conditions (Narang and Gulati 1995). Resource conservation technologies such as ridge and furrow and raised bed planting have been found very effective in saving water in crop production (Gupta and Zaidi 2004). The use of raised beds for the production of irrigated non-rice crops was pioneered in the heavy clay soils of the rice growing region in Australia

in the late 1970s (Maynard 1991) and for irrigated wheat in the rice-wheat areas of the Indo-Gangetic Plain (IGP) during the 1990s, inspired by the success of beds for wheat-maize systems in Mexico (Meisner *et al.* 1992, Sayre and Hobbs 2004). Bed planting of crops result in reduced irrigation amounts or time, with similar or higher yields, for wheat on beds compared with conventional tilled wheat, from farmer participatory trials and researcher plots across the IGP. Typical irrigation savings range from 18% to 30-50% (Hossain *et al.* 2001, Talukder *et al.* 2002, Hobbs and Gupta 2003).

Proper scheduling of irrigation (amount and timing) to crops is an important component of water saving technologies. There are numerous ways to schedule irrigations and estimate the required depth of water application (Campbell and Campbell 1982, Raju *et al.* 1983, Stegman 1983, Prihar *et al.* 1997). All irrigation scheduling methods consist of monitoring indicators that determine the need for irrigation. Prihar *et al.* (1974) suggested a simple approach based on meteorological parameters to schedule irrigation to crops based on the ratio between fixed depth (75 mm) of irrigation water (IW) and net cumulative pan evaporation since previous irrigation (PAN-E minus rainfall). Irrigating wheat using this approach (IW/PAN-E = 0.9) saves 2 irrigation compared to 5-6 irrigations at fixed growth stages without any yield loss (Prihar and Sandhu 1987). Being the prime natural resource for assured crop production, water has to be used judiciously and in scientific manner. To increase availability of irrigation water there is need to quantify the irrigation water by using

<sup>1</sup>Principal Scientist, <sup>2</sup>Technical Officer, Division of Agronomy

improved irrigation method and proper scheduling of irrigation to obtain more yield and economic returns. The objective of this research was to evaluate the effects of irrigation schedules on wheat yield, water use, economics, physical properties of soil and nutrient uptake under different planting methods.

## MATERIALS AND METHODS

The field experiments were carried out at the research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi located at 28°04'N latitude and 77°12'E longitude at an altitude of 228.61 above mean sea level during *rabi* 2007-08 and 2008-09 at a same site in both the years. The region is characterized by a sub-tropical and semi-arid climate with a hot dry summer (March–June), wet monsoon season (late June–mid September) and a cool, dry winter (October–February). Average annual rainfall is 734 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon. The soil was sandy loam with pH 7.3 and 7.2 (1:2.5 soil to water). The top soil of the experimental site was clay loam overlying silty clay, with an abrupt change to sandy loam at about 90 cm. Bulk density was 1.50 g/cm in the top-soil, and there was a hard pan (1.71 g/cm) at 15–30 cm. Organic carbon 0.37 and 0.38%, available N 155.5 and 160.4 kg/ha available K 162.1 and 166.3 kg/ha and available P 9.7 and 10.1 kg/ha at the start of the experiment in 0 to 30 cm soil layer during 2007–08 and 2008–09, respectively. The treatments consists of three planting systems ( $M_1$ , Conventional,  $M_2$ , FIRBS and  $M_3$ , side sowing on ridges) and five irrigation schedules ( $I_1$ , Irrigation at CRI,  $I_2$ , CRI + 200 mm CPE;  $I_3$  - CRI + 150 mm CPE;  $I_4$ , CRI + 100 mm CPE;  $I_5$ , CRI + 50 mm CPE). The study was made in strip plot design with three replications. In FIRBS, 15 cm high and 45 cm broad bed with a furrow width of 25 cm between the beds was prepared with planting three rows of wheat in rows 15 cm apart (Jat *et al.* 2005). Half dose of N and full dose of P and K through urea, single super phosphate and muriate of potash, respectively, were applied at sowing and remaining N was applied after first irrigation. Farmyard manure @ 5 tonnes/ha containing 0.49-0.37- 0.55% N-P-K was applied one month prior to sowing. Wheat HD 2285 was sown on 30 November and 27 November 2007 and 2008 and harvested on 10 April and 7 April, in 2008 and 2009, respectively. Other management practices were adopted as per recommendations of the crop under irrigated conditions. The nutrient uptake by the crops was obtained as product of nutrient concentration and yield. Two years data was pooled and statistically analyzed.

## RESULTS AND DISCUSSION

### Yield

The grain (4.765 tonnes/ha) and biological (11.030 tonnes/ha) yields and harvest index (0.432) of wheat varied

significantly due to planting systems. These were significantly the highest under FIRBS. FIRBS registered a 27.9% higher grain yield over conventional system (3.531 tonnes/ha). Higher grain yield with bed planting of wheat has been also reported by Thind *et al.* (2010) and Bhahma *et al.* (2007). The increase in grain yield of wheat under FIRBS could be attributed to higher yield attributes, whereas the increase in biological yield was due to higher plant height and dry matter accumulation. Higher grain and biological yields and harvest index recorded in FIRBS could also be attributed to better soil environment in raised beds since prolonged ponding reduces yield. On interpretation of data on the grain yield of wheat, significant superiority of treatment receiving CRI + 100 mm CPE was observed over other irrigation schedules during both the years of study. Among different treatments, the treatment, CRI + 100 mm CPE produced significantly the highest grain yield (4.684 tonnes/ha). It yielded 31.1 per cent higher grain yield over the treatment receiving irrigation only at CRI stage (3.572 tonnes/ha). This was closely followed by the treatment receiving CRI + 150 mm CPE (4.026 tonnes/ha).

### Water use parameters

FIRBS recorded the lowest consumptive use of water (30.07 cm) and the highest water-use efficiency (147.6 kg/ha-cm) in comparison to other methods of sowing. Among irrigation schedules, irrigation at CRI + 100 mm CPE recorded the highest water-use efficiency (142.5 kg/ha-cm). The lowest consumptive use of water in FIRBS was probably because of the nature of land configuration where in least quantity of water was applied as well as consumed. As per the nature of other land configurations, the consumptive use of water was more in side sowing on ridges and the highest in conventional. The reason for the highest water-use efficiency in the said treatments could be attributed to relatively higher economic yield and lower consumptive use of water.

### Organic properties of soil

Among different sowing methods, FIRBS showed significantly the least bulk density (1.44 g/cm<sup>3</sup>) and significantly the highest cumulative infiltration (8.07 cm/hr). Whereas, side sowing on ridges recorded significantly the highest bulk density (1.50 g/cm<sup>3</sup>) and significantly the lowest cumulative infiltration (7.75 cm/hr). The highest cumulative infiltration in FIRBS was due to the least bulk density in this treatment. Similarly, irrigation at CRI + 100 mm CPE registered significantly the least bulk density (1.40 g/cm<sup>3</sup>) and significantly the highest cumulative infiltration (8.21 cm/hr). Irrigation at CRI + 100 mm CPE recorded the highest bulk density (1.51 g/cm<sup>3</sup>) and significantly the lowest cumulative infiltration (7.68 cm/hr). This also draws the same reasoning.

### Nutrient uptake

Among different sowing methods, FIRBS showed

Table 1 Effect of irrigation schedules and sowing method on yield, economics and water use parameters of wheat

| Treatment                   | Grain yield<br>(tonnes/ha) | Straw yield<br>(tonnes/ha) | Harvest<br>index | Net return<br>(₹/ha) | B:C ratio | CUW<br>(cm) | WUE<br>(kg/ha-cm) |
|-----------------------------|----------------------------|----------------------------|------------------|----------------------|-----------|-------------|-------------------|
| <i>Method of sowing</i>     |                            |                            |                  |                      |           |             |                   |
| FIRBS                       | 4.765                      | 11.030                     | 0.432            | 31 586               | 3.07      | 30.07       | 158.5             |
| Side sowing on ridges       | 3.726                      | 9.00                       | 0.414            | 28 204               | 2.91      | 31.14       | 119.7             |
| Conventional                | 3.531                      | 8.8275                     | 0.400            | 24 728               | 2.24      | 32.28       | 109.4             |
| CD (5%)                     | 0.3427                     | 1.4219                     | 0.0241           | 2 250                | 0.126     |             |                   |
| <i>Irrigation schedules</i> |                            |                            |                  |                      |           |             |                   |
| Irrigation at CRI           | 3.572                      | 8.8855                     | 0.402            | 23 110               | 2.16      | 28.73       | 124.3             |
| CRI + 200 mm CPE            | 3.754                      | 9.1116                     | 0.412            | 24 604               | 2.22      | 30.14       | 124.6             |
| CRI + 150 mm CPE            | 4.026                      | 9.4952                     | 0.424            | 28 740               | 2.94      | 31.26       | 128.8             |
| CRI + 100 mm CPE            | 4.684                      | 10.867                     | 0.431            | 32 345               | 3.27      | 32.87       | 142.5             |
| CRI + 50 mm CPE             | 3.812                      | 9.0978                     | 0.419            | 25 180               | 2.34      | 33.36       | 114.3             |
| CD (5%)                     | 0.2927                     | 1.3872                     | 0.0211           | 1 020                | 0.117     |             |                   |

Table 2 Effect of irrigation schedules and sowing methods on soil physical properties, organic carbon and nutrient uptake by wheat

| Treatment                   | Bulk density<br>(g/cm <sup>3</sup> ) | Cumulative infiltration<br>(cm/hr) | Organic carbon (%) | N (kg/ha) | P <sub>2</sub> O <sub>5</sub> (kg/ha) | K <sub>2</sub> O (kg/ha) |
|-----------------------------|--------------------------------------|------------------------------------|--------------------|-----------|---------------------------------------|--------------------------|
| <i>Method of sowing</i>     |                                      |                                    |                    |           |                                       |                          |
| FIRBS                       | 1.44                                 | 8.07                               | 0.456              | 79.14     | 22.06                                 | 93.17                    |
| Side sowing on ridges       | 1.50                                 | 7.75                               | 0.335              | 72.72     | 18.21                                 | 80.36                    |
| Conventional                | 1.47                                 | 7.89                               | 0.432              | 70.21     | 17.08                                 | 78.23                    |
| CD (5%)                     | 0.02                                 | 0.15                               | NS                 | 6.035     | 1.878                                 | 8.57                     |
| <i>Irrigation schedules</i> |                                      |                                    |                    |           |                                       |                          |
| Irrigation at CRI           | 1.51                                 | 7.68                               | 0.330              | 69.21     | 17.12                                 | 77.28                    |
| CRI + 200 mm CPE            | 1.48                                 | 7.86                               | 0.433              | 70.63     | 17.88                                 | 78.67                    |
| CRI + 150 mm CPE            | 1.44                                 | 8.07                               | 0.450              | 74.62     | 19.24                                 | 84.23                    |
| CRI + 100 mm CPE            | 1.40                                 | 8.21                               | 0.468              | 79.42     | 21.84                                 | 92.87                    |
| CRI + 50 mm CPE             | 1.40                                 | 8.21                               | 0.468              | 74.25     | 16.16                                 | 83.23                    |
| CD (5%)                     | 0.04                                 | 0.17                               | NS                 | 5.924     | 1.623                                 | 8.16                     |

significantly the highest nitrogen, phosphorus and potassium uptake 79.14, 22.06 and 93.17 kg/ha, respectively, by wheat. Whereas, conventional method of sowing recorded significantly the lowest nitrogen, phosphorus and potassium uptake 70.21, 17.08 and 78.23 kg/ha, respectively, by wheat. Similarly, irrigation at CRI + 100 mm CPE registered significantly the highest nitrogen, phosphorus and potassium uptake 79.42, 21.84 and 92.87 kg/ha, respectively, by wheat followed by irrigation at CRI + 150 mm CPE valuing nitrogen, phosphorus and potassium uptake 74.62, 19.24 and 84.23 kg/ha, respectively. The trend of nutrient uptake is in the direction of the trend of grain yield.

#### Economics

FIRBS registered significantly the highest net return and benefit: cost ratio (₹ 31 586 and 3.07, respectively) as compared to side sowing on ridges and conventional planting during both the years of study. This could be ascribed to relatively the highest yield in this treatment. In case of the irrigation schedules significantly the highest net return and

benefit: cost ratio (₹ 32 345 and 3.27, respectively) was recorded in irrigation at CRI + 100 mm CPE as compared to remaining treatments. The same reason could be ascribed to this as well.

#### CONCLUSIONS

The study indicated an improvement in growth attributes, yield attributes and yield of wheat under FIRBS as compared to other method of planting. In case of irrigation schedules, irrigation at CRI + 100 mm CPE (four irrigations) gave higher yield as compared to other irrigation schedules in Delhi condition. The same reason could be ascribed to this as well.

#### REFERENCES

- Bahma R, Janawade A D and Palled Y B. 2007. Water-use studies in durum wheat as influenced by irrigation schedules, mulch and antitranspirant application in black soils of northern transitional zone of Karnataka. *Karnataka Journal of Agricultural Science* 20(1): 120-2.
- Campbell G S and Cambell M D. 1982. Irrigation scheduling using soil moisture measurements: Theory and practice. (*In*) *Advances*

- in *Irrigation*, Vol 1, pp 25-42. Hillel D (Ed). Academic Press, New York.
- Ehsan Ghane, Mohammad Feizi, Behrouz Mostafazadeh-Fard and Esmail Landi. 2009. Water productivity of winter wheat in different irrigation/planting methods using saline irrigation water. *International Journal of Agriculture & Biology* 11.
- Gupta R K and Zaidi P H. 2004. Potential of resource conservation technologies in enhancing use-efficiency of groundwater resources in the Indo-Gangetic Plains. (In) *Groundwater Use in North-west India*. Workshop papers. Abrol I P, Sharma B R and Sekhon G S (Eds). Centre for Advancement of Sustainable Agriculture (CASA), New Delhi.
- Hasan Kilic. 2010 The effect of planting methods on yield and yield components of irrigated spring durum wheat varieties. *Scientific Research and Essays* 5(20): 3 063–9.
- Hobbs P R and Gupta R K. 2003. Rice-wheat cropping systems in the Indo-Gangetic Plains: issues of water productivity in relation to new resource-conserving technologies. (In) *Water Productivity in Agriculture: Limits and Opportunities for Improvement*. Kijne J W, Barker R and Molden D (Eds). CABI, Wallingford.
- Hossain M I, Talukder A S M H M, Sufian M A, Hossain A B S and Meisner C A. 2001. Performance of bed planting and nitrogen fertilizer under rice-wheat - mungbean cropping systems in Bangladesh. [www.cimmyt.org/bangladesh/](http://www.cimmyt.org/bangladesh/)
- Jat M L, Singh Samar, Rai H K, Chhokar R S, Sharma S K and Gupta R K. 2005. Furrow irrigated raised bed (FIRB) planting technique for diversification of rice-wheat system in Indo-Gangetic Plains. *Japan Association for International Collaboration of Agriculture and Forestry* 28(1): 25–42.
- Maynard M. 1991. Permanent beds – their potential role in soil management for the future. *Farmers' Newsletter Large Area* 137: 14–8.
- Meisner C A, Acevedo E, Flores D, Sayre K, Ortiz-Monasterio I, Byerlee D and Limon A. 1992. Wheat production and grower practices in the Yaqui Valley, Sonora, Mexico. Wheat Special Report 6, CIMMYT, Mexico City, Mexico.
- Narang R S and Gulati H S. 1995. On-farm water management. Symposium on. Water Management (Need for Public Awareness). Punjab Agricultural University, Ludhiana.
- Prihar S S and Khepar S D. 1997. Resource management for sustainable intensive agriculture– water. Proc. Third Agricultural Science Congress, National Academy of Agricultural Sciences, Ludhiana, pp 91–101.
- Prihar S S and Sandhu B S 1987. *Irrigation of Field Crops – Principles and Practices*. Indian Council of Agricultural Research (ICAR), New Delhi.
- Prihar S S, Gajri P R and Narang R S. 1974. Scheduling irrigation to wheat using open pan evaporation. *Indian Journal of Agricultural Science* 44:567–71.
- Raju K S, Biere A W, Kanemasu E T and Lee E S. 1983. Irrigation scheduling based on a dynamic crop response model. (In) *Advances in Irrigation*, Vol 2, pp 257–71. Hillel D (Ed). Academic Press, New York.
- Sayre K D and Hobbs P R. 2004. The raised-bed system of cultivation for irrigated production conditions. (In) *Sustainable Agriculture and the International Rice-Wheat System*. Lal R, Hobbs P R, Uphoff N and Hansen D O (Eds). Marcel Dekker, Inc., New York.
- Stegman E C. 1983. Irrigation scheduling: applied timing criteria. (In) *Advances in Irrigation*, Vol 2, pp 1-30. Hillel D(Ed). Academic Press, New York.
- Talukder A S M H M, Sufian M A, Meisner C A, Duxbury J M, Lauren J G and Hossain A B S. 2002. Enhancing food security in warmer areas through permanent raised-bed in wheat: save water and reduce global warming. Poster paper at 2nd International Group Meeting on Wheat Technologies for Warmer Areas, 23-26 September 2002. Agharkar Research Institute, Pune, India. [www.cimmyt.org/bangladesh/](http://www.cimmyt.org/bangladesh/)
- Thind H S, Buttar G S and Aujla M S 2010. Yield and water use efficiency of wheat and cotton under alternate furrow and check-basin irrigation with canal and tube well water in Punjab, India. *Irrigation Sciences* 28: 489–96.