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Water productivity and energy efficiency of wheat (*Triticum aestivum*) as influenced by methods and dates of sowing and irrigation regimes

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ABSTRACT

The field experiment was conducted during Rabi season of 2017-19 at Khalsa College, Amritsar (Punjab) to study the influence of methods and dates of sowing and irrigation regimes on water productivity and energy efficiency of wheat (Triticum aestivum). The results revealed thatconventional method produced significantly higher yield by 27.9% (45.70 q ha^{-1}) over zero tillage (35.72 q ha^{-1}). The grain and straw yields produced by crop sown on 10 November (44.41 and 82.62 q ha^{-1}, respectively) were significantly higher than crop sown on 10 December (34.04 and 64.14 q ha^{-1}, respectively) but were at par with crop sown on 25 November (43.67 and 81.93 q ha^{-1}, respectively). The grain and straw yields produced by crop irrigated at 40% ASM (46.91 and 87.89 q ha^{-1} respectively) were significantly higher than crop irrigated at 30% ASM (36.26 and 68.94 q ha^{-1}, respectively) and 20% ASM (38.88 and 71.85 q ha^{-1}, respectively). In zero tillage highest water productivity was observed in crop sown on 10 November and irrigated at 20% ASM where as in conventional tillage higher water productivity was reported in crop sown on 25 November and irrigated at 20% ASM. The maximum energy efficiency was observed in zero till sown crop on 10 November and irrigated at 40% ASM. The crop sown on 10 November by zero till and irrigated at 40% ASM and conventional, 25 November and irrigated at 20% ASM produced maximum value of energy productivity.

Key words: Grain yield, irrigation regimes, sowing dates, zero tillage, wheat

INTRODUCTION

Wheat (*Triticum aestivum*) is one of the most important cereal crops of India. In India it was grown on about 30.6 million hectares of land. The Production of wheat in India during 2018-19 was 99.70 million tonnes. In Punjab, 3480 thousand hectares of wheat crop was grown which produced 17.83 million tonnes with productivity of 4700 kg ha^{-1} in year 2017-18. Zero tillage is a conservative technology to avoid various issues of Indo-Gangetic plains such as burning of crop residues and degradation of soil. Therefore, with the help of zero tillage system we can conserve the time and energy as well as we can reduce erosion, improve the soil environment for crop growth and decrease the cost of cultivation. Zero tillage technology is gaining popularity in rice-wheat system in India, as this technology not only reduces the incidence of most problematic weeds '*Phalaris minor'* in wheat, but also improves the input use efficiency. When crop is sown at optimum time, it produces highest yield as it escape from drought, heat and diseases which became more prevalent as season advances (Sharma et.al. 2018). When crop is sown too early, temperature is above optimum which causes irregular germination due to frequent death of embryos and decomposition of endosperm. Late planting results in poor tillering and have more chances of winter injury.

Wheat crop in Indo-Gangetic plain is grown in the period when there is very poor to no rainfall. The evapo-transpirational losses are more as compared to precipitation. Excessive irrigation increases evapo-transpiration and decreases water use efficiency and can also reduce grain yield. Available soil moisture technique can also be used to estimate the water needs of the crop. It is postulated that 75% of available soil moisture is needed for better crop stand. At the same time critical stage approach is also used for better yields. The most moisture sensitive stage is crown root initiation stage which comes after 21 days of sowing. Lack of moisture at CRI, heading, grain formulation and during maturity significantly reduced the yield of wheat grain (Shirazi *et al.* 2014). Hence the field experiment was performed to evaluate the effect of methods of sowing, irrigation regimes and dates of sowing on yield, water and energy productivity of wheat.

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MATERIALS AND METHODS

The field study was conducted at the Students' Research Farm, Khalsa College, Amritsar during two consecutive cropping seasons i.e. *Rabi* 2017-18 and 2018-19. Amritsar is located at 31.63ºN and 74.87°E with an average elevation of 234 meters (768 ft). The maximum and minimum temperatures show considerable fluctuation during both summer and winter season. Maximum temperature goes above 47°C during summer, while temperature below 4°C accompanied by frosty spells is quite common during the months of December and January. The average annual rainfall is about 500-750 mm, most of which is received during the monsoon period from July to September. However a few showers were received during winter season also. The experiment was laid out in split-split plot design with three replications consisted two main plot treatments (methods of sowing) i.e. zero (M_1) and conventional (M_2) tillage, three dates of sowing (sub plots) i.e. 10 November (D_1), 25 November (D_2) and 10 December (D_3) and three irrigation regimes (sub-sub plots) i.e. 40% ASM (I_1), 30% ASM (I_2) and 20% ASM (I_3). All the standard agronomic practices were adopted to grow the crop. Water measurement was done for the calculation of Water Productivity.

$$WP = \frac{grain yield}{water\ applied\ at\ different\ levels\ of\ irrigation\ regimes} kgm^{-3}$$

V-Notch a triangular thin plate weir was used to measure the flow of irrigation system.

Formula:

$$Q = 1.38\ H^{2.50}$$

Where, Q = discharge in m^3/sec, H= difference between the crest and water surface at point upstream from the weir at a distance of four times the maximum head on the crest (m).
Data related to water use, fertilizer, chemicals used for plant protection, and energy consumed in land preparation, pumping water and machinery operations etc for seasons were collected. The data were pooled over two seasons and subjected to statistical analysis. All inputs except volume of irrigation water were the same for all treatments. The amount of first irrigation water was the same for all treatments to obtain better emergence. Energy equivalents (extracted from a scientific source) were used to calculate the energy input and output. The energy equivalents used in this study are shown below. Energy input of each treatment was calculated from the data for each item of operations as expressed in mega joules (MJ ha^{-1}) taking standard values. Similarly grain and straw yields were also converted into energy units and then added to get gross energy output.

Energy	Unit	Energy equivalent $unit^{-1}$
Input		
Field preparation by rotavator	Hr	657.08
Sowing	Hr	34.3
Seed	Kg	14.7
Fertilization		
N	Kg	60.6
P_2O_5	Kg	11.1
Weeding	Kg	238
Water	m^3	1.02
Plant protection	Kg	238
Human labour	Hr	1.96
Machinery	Hr	62.7
Output		
Wheat grain	Kg	14.7
Wheat straw	Kg	12.5

The following formulae were used to calculate energy efficiency, specific energy, energy productivity and net energy output:

$$Energy\ Efficiency = \frac{Energy\ Output\ (MJ/ha)}{Energy\ Input\ (MJ/ha)}$$

$$Specific\ Energy = \frac{Energy\ Output\ (MJ/ha)}{Grain\ Output\ (kg/ha)}$$

$$Energy\ Productivity = \frac{Grain\ Output\ (kg/ha)}{Energy\ Output\ (MJ/ha)}$$

$$Net\ Energy = Energy\ output\ (MJ/ha) - Energy\ input\ (MJ/ha)$$

RESULTS AND DISCUSSION

Effect on wheat grain yield

The significantly higher grain yield was produced by wheat crop sown by conventional method (45.70 q ha^{-1}) over zero tillage method (35.72 q ha^{-1}) of sowing. The increase in grain yield of wheat crop sown under conventional method of sowing was 27.9 % over zero tillage

method of sowing.

Table 1: Effect of methods and dates of sowing and irrigation regime on grain yield of wheat (mean of 2 years)

Treatment	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})
Method of sowing		
Zero (M_1)	35.72	68.17
Conventional (M_2)	45.70	84.28
CD (0.05)	3.16	9.38
Date of sowing		
10 November (D_1)	44.41	82.62
25 November (D_2)	43.67	81.93
10 December (D_3)	34.04	64.14
CD (0.05) sub plot	1.61	2.44
CD (0.05) main * subplot	2.27	3.45
Moisture regimes		
40% ASM (I_1)	46.91	87.89
30% ASM (I_2)	36.26	68.94
20% ASM (I_3)	38.88	71.85
CD (0.05) sub-sub plot	3.09	4.39
CD (0.05) main * sub-sub plot	4.38	6.20
CD (0.05) sub*sub-sub plot	NS	NS
CD (0.05) main*sub*sub-sub	NS	NS

The positive effect of conventional tillage on grain yield might be attributed to better physical and hydrological conditions. Similar results were found by Mazzoncini *et al.* (2011). With delay in sowing, yield decreased significantly. The grain yield produced by crop sown on 10 November (44.41 q ha^{-1}) was significantly higher over grain yield of crop sown on 10 December (34.04 q ha^{-1}) but it was at par with crop sown on 25 November (43.67 q ha^{-1}). The increases in grain yield sown on 10 December were 30.5 % and 28.3% as compared to crop sown on 10 November and 25 November respectively. Similar results were found by Qasim *et al.* (2008).The yield of crop irrigated at 40% ASM (46.98 q ha^{-1}) was significantly higher over the crop irrigated at 30% ASM (36.26 q ha^{-1}) and 20% ASM (38.88 q ha^{-1}). The increases in the grain yield at 40% ASM were 22.82 % and 17.24 % as compared to crop irrigated at 30% ASM and 20% ASM, respectively. Mahmood and Ahmad (2005) reported similar findings. Crop irrigated at 20% ASM produced more yield than 30% ASM crop because irrigations at 20% ASM coincide with critical stages.

The interactions effect between method of sowing and date of sowing was also found significant (Table 1). The grain yield produced by crop under conventional method on November 25 (51.72 q ha^{-1}) was significantly higher than grain yield produced by crop by zero tillage method on November 10 and November 25 (38.38 and 35.61 q ha^{-1} respectively) but was at par with crop sown by conventional method on November 10(50.43 q ha^{-1}). The crop sown on December 10 by conventional and zero tillage method (34.94 and 33.15 q ha^{-1}) produced statistically similar yield. The interaction effect between method of sowing and irrigation regimes was also significant (Table 1). The grain yield produced by wheat crop under conventional tillage and irrigated at 40% ASM (43.39 q ha^{-1}) was significantly higher than grain yield of the crop under zero tillage and irrigated at 30% and 20% ASM (29.34 and 31.24 q ha^{-1}respectively) but at par with zero till sown irrigated at 40% ASM crop (46.57 q ha^{-1}) and conventional sown crop irrigated at 20% and 30% ASM (46.51 and 43.18 q ha^{-1}). Similar results were found by Sarker *et al.* (2012) and Meena *et al.* (2015).

Water productivity

Water productivity helps in understanding the yield produced by using a unit of water (Table 2). Maximum water productivity was recorded in crop sown by conventional method on 25 November and irrigated at 20% ASM. In zero till sown wheat, maximum water productivity was observed in crop sown on 25 November and irrigated at 40% ASM. Water used for irrigation in zero till sown wheat is lesser as compared to conventional method of sowing. Least water productivity was observed in crop sown by conventional method on 10th December and irrigated at 30% ASM.

Table 2: Effect of methods and dates of sowing and irrigation regime on water productivity of wheat (mean of 2 years)

Treatment	Rainfall (m^3 ha^{-1})	Irrigation (m^3 ha^{-1})	Total irrigation (m^3 ha^{-1})	Yield (kg/ha)	Water productivity (kg m^{-3})
Zero+10Nov+40%ASM	1821	2550	4371	5003.5	1.14
Zero+10Nov+30%ASM	1821	1530	3351	3040.3	0.91
Zero+10Nov+20%ASM	1821	1020	2841	3471.4	1.22
Zero+25Nov+40%ASM	1821	2040	3861	4824.6	1.25
Zero+25Nov+30%ASM	1821	1420	3241	2917.2	0.90
Zero+25Nov+20%ASM	1821	1020	2841	2942.0	1.04
Zero+10Dec+40%ASM	1821	2040	3861	4143.1	1.07
Zero+10Dec+30%ASM	1821	1420	3241	2843.5	0.88
Zero+10Dec+20%ASM	1821	1020	2841	2959.5	1.04
Conventional+10thNov+40%ASM	1821	3800	5621	5171.4	0.92
Conventional+10thNov+30%ASM	1821	2280	4101	4928.4	1.20
Conventional+10thNov+20%ASM	1821	1520	3341	5030.4	1.51
Conventional+25thNov+40%ASM	1821	3040	4861	5312.3	1.09
Conventional+25thNov+30%ASM	1821	2120	3941	5028.6	1.28
Conventional+25thNov+20%ASM	1821	1520	3341	5176.3	1.55
Conventional+10thDec+40%ASM	1821	3040	4861	3733.8	0.77
Conventional+10thDec+30%ASM	1821	2120	3941	2997.9	0.76
Conventional+10thDec+20%ASM	1821	1520	3341	3748.9	1.12

Energetics

The energy input in zero tillage is less as compared to the conventional tillage as the tillage practices are exempted. The energy input in 40% ASM is more as compared to the 30% ASM and 20% ASM because more water (m^3 ha^{-1}) is used in 40% ASM treatment. The maximum value of energy output is observed in conventional sown crop irrigated at 40% ASM and sown on 25 November. The maximum energy efficiency was observed in zero till sown crop on 10 November and irrigated at 40% ASM. The crop sown on 10 November by zero till sown crop and irrigated at 40% ASM and conventional, 25 November sown crop and irrigated at 20% ASM produced maximum value of energy productivity (Table 3).

Table 3: Effect of methods and dates of sowing and irrigation regimes on energy efficiency of wheat (mean of 2 years)

Treatment	Energy input (MJ ha^{-1})	Energy output (MJ ha^{-1})	Energy efficiency	Specific energy	Energy productivity
Zero+10Nov+40%ASM	19486.86	179258.1	9.20	3.89	0.26
Zero+10Nov+30%ASM	18446.46	124670.2	6.76	6.07	0.16
Zero+10Nov+20%ASM	17926.26	137780.3	7.69	5.16	0.19
Zero+25Nov+40%ASM	18966.66	170071.6	8.97	3.93	0.25
Zero+25Nov+30%ASM	18334.26	118816.5	6.48	6.28	0.16
Zero+25Nov+20%ASM	17926.26	125135.4	6.98	6.09	0.16
Zero+10Dec+40%ASM	18966.66	144487.7	7.62	4.58	0.22
Zero+10Dec+30%ASM	18334.26	120604.3	6.58	6.45	0.16
Zero+10Dec+20%ASM	17926.26	124838.9	6.96	6.06	0.17
Conventional+10thNov+40%ASM	22076	176430.3	7.99	4.27	0.23
Conventional+10thNov+30%ASM	20525.6	168258.7	8.20	4.16	0.24
Conventional+10thNov+20%ASM	19750.4	171243.4	8.67	3.93	0.25
Conventional+25thNov+40%ASM	21300.8	181663.2	8.53	4.01	0.25
Conventional+25thNov+30%ASM	20362.4	168866.7	8.29	4.05	0.25
Conventional+25thNov+20%ASM	19750.4	177396.6	8.98	3.82	0.26
Conventional+10thDec+40%ASM	21300.8	142518.2	6.69	5.70	0.18
Conventional+10thDec+30%ASM	20362.4	128899	6.33	6.79	0.15
Conventional+10thDec+20%ASM	19750.4	145951.8	7.39	5.27	0.19

From the results it may be concluded that higher yield of wheat was produced in crop sown by conventional method of sowing on 25 November and irrigated at 40% ASM. In zero tillage, highest water productivity was observed in crop sown on 25 November and irrigated at 40% ASM where as in conventional tillage higher water productivity was reported in crop sown on 25 November and irrigated at 20% ASM. The energy efficiency was higher in crop sown by zero tillage method on 10 November and irrigated at 40% ASM than other treatments.

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