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Quantifying water productivity using seed priming and micro irrigation in wheat (Triticum aestivum)

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Abstract

Field studies were conducted during the four rabi seasons (2011-12 to 2014-15) to investigate the impact of seed priming and micro irrigation on crop establishment, growth, productivity, and water productivity in wheat under different moisture regimes. Results indicated that sprouted seed (5830 kg ha⁻¹) and primed seed (5766 kg ha⁻¹) produced significantly higher grain yield in comparison to un-primed seeds (5416 kg ha⁻¹). The germination was quick in the primed and sprouted seeds relative to non-primed seeds resulting in a better crop establishment and higher yield under optimum, sub-optimum and dry soil conditions. Irrigation method treatments viz., check basin, drip, sprinkler and drip + rainport showed that the grain yield was highest in the drip + rainport. Water productivity was highest in drip method of irrigation (1.61 kg m⁻³) followed by drip + rainport method (1.60 kg m⁻³) with a maximum mean productivity of 5539 kg ha-1. Around 600 m3ha-1 has been saved using seed priming thus reducing the cultivation cost by Rs. 382/ha. Among the micro irrigation techniques, water saved was highest in drip followed by sprinkler and drip + rainport. The study suggests for adoption of drip and seed priming to take advantage of yield enhancement as well as cost reduction through reduced utilisation of water.

Key words: Micro irrigation; seed priming; water productivity; wheat yield

1. Introduction

Ensuring food security through irrigated agriculture is widely advocated by researchers since it influences the crop yield significantly. However, improving the efficiency and productivity of water in agriculture is a daunting task on sustainability front. In the era of precision agriculture, it becomes an utmost priority to use the water rationally as the utilization over years has been alarming particularly in the Indo-Gangetic Plains (IGP). The depleting water resources endanger the future need of irrigation water as well as sustainable food production. It is estimated that water needed for wheat in India hovers around 1500 litres per kg of grain production (FAO, 2012). In India around 97 per cent of the crop area is grown under irrigated condition

and consumes approximately 127,671 million m³ (16% of global water footprint in wheat) per annum. Among the precision water saving technologies, seed priming and micro irrigation technologies registered better efficiency and productivity coupled with supplementary benefits (Meena et al., 2015; Mondal and Bose, 2014; Shabbir et al., 2014; Meena et al., 2013; Rajpar et al., 2006; Clark et al., 2001, Harris and Hollington, 2001; Harris et al., 1999; Harris, 1996). In the milieu, the present study was proposed to investigate the effect of seed priming (matriconditioning) and micro irrigation on wheat yield and to quantify the water savings from these techniques.

2. Material and methods

Precision field experiments on seed priming and micro irrigation using split plot design and randomized block design respectively were conducted at the ICAR-Indian Institute of Wheat and Barley Research, Karnal (29°43'N, 76°58'E and 245m AMSL), located at Karnal, Haryana. The average annual rainfall of Karnal is 744 mm, of which about 80 percent is received during the monsoon. The mean minimum temperature ranged between 6-7°C in winter. The experiments were conducted for four consecutive Rabi seasons from 2011-12 to 2014-15. Under seed priming, three main plot treatments viz., seeding at optimum moisture, seeding at sub-optimal moisture and seeding in dry soil; and three sub plot treatments viz., no seed priming, seed priming and sprouted seed were carried out. Seed priming was planned in wheat since the process advances the crop sowing by about 10-15 days by avoiding the pre-sowing irrigation. The fortnight duration is very crucial in rice-wheat cropping system as the planting of wheat usually gets delayed under this system due to late harvesting of rice which can cause yield penalty. Further, there will be poor establishment of wheat due to lack of optimum soil moisture. Seed priming was carried out in gunny bags (Basra et al., 2003). For seed priming, soaked seeds were placed overnight in gunny bags and thereafter spread between two gunny bags. The gunny bags were kept under moist condition for the whole treatment period *i.e.* 12 hours. For sprouting treatment, the seeds were soaked in fresh water for 10 hours and then spread between two wet gunny bags for 14 hours. The experiment on irrigation consisted of four treatments (micro irrigation – drip, sprinkler and drip + rainport techniques – against check basin irrigation). The drip+rainport combo treatment was carried out to mitigate the terminal heat stress, a serious issue in wheat that hamper the crop productivity. For this water was sprinkled for 15 minutes by sprinkler system whenever the day temperature crosses 30°C at noon to mitigate the heat stress. All recommended package of practices except irrigation and fertilizer application, were followed. Further, the physical water productivity was estimated (Abdullaev et al., 2007). Water productivity in kg m-3 is the ratio of wheat output in kg ha-1 to the estimated water footprint in m³ha-¹. The total water footprint was estimated by multiplying the total hours of irrigation during a season with the volume of water extracted per hour apart from the amount of rainfall received.

Based on this, the average discharge of tube well of 10 HP was estimated as 600m³ha-¹ per irrigation (Kaur *et al.*, 2012). SAS (Statistical Analysis System) version 10.3 was used to analyze the recorded observations.

3. Results and discussion

Experiments on seed priming and seeding methods revealed significant effect of seed priming treatments but seeding method had non significant effect. The highest yield was obtained in sowing of sprouted seeds (5831 kg ha-¹) followed by sowing of primed seeds (5767 kg ha-¹). Both these treatments were significantly better than the no priming treatment (Table 1). The yield gain is attributed to better germination, crop stand and establishment corroborating the earlier research findings (Harris *et al.*, 2001; Rashid *et al.*, 2002; Musa *et al.*, 1999).

The results of experiment on micro irrigation revealed that the maximum yield was recorded in drip+rainport treatment (5539 kg ha⁻¹) with a water use efficiency of 1.60 kg.m⁻³, followed by check basin method (5301 kg ha-1) but with the minimum water productivity of 1.22 kg.m⁻³ (Table 1). Drip irrigation produced 5205 kg ha⁻¹ with the water use efficiency of 1.61 kg.m⁻³ and sprinkler irrigation registered 5194 kg ha-1 with the water use efficiency of 1.58 kg.m⁻³. Water footprints comprising fresh water irrigation and rainfall indicated that seed priming consumed less water in comparison to unpriming (Table 1 and 2) with seeding at sub-optimal soil moisture level registering the lowest footprint (Table 1). Similarly, under micro irrigation systems, drip technique resulted in less water footprint in comparison to others. The water productivity per hectare was highest in the case of sprouted seed technique coupled with seeding in sub-optimal soil moisture level (M3S2).

Overall, the water productivity was found to be more under micro irrigation system (drip and sprinkler irrigation) and relatively efficient in comparison to surface irrigation method (full irrigation approach). Further, it helped to save around 31% of water apart from labour saving and drudgery reduction. Stress for water is the possible reason for the low yield obtained in surface irrigation methods as the number of irrigations is low in this case relative to micro irrigation. Further, large irrigation interval after January coinciding with the stem elongation stage might lead to reduction in the number of productive tillers per unit area. Insufficient irrigation water applied in March during the heading

and flowering stage, which coincides with high evapotranspiration, adversely affected the grain formation. The results corroborate the findings of Zhang and Oweis (1999) that the crop sensitivity to water stress occurs from zadoks scale 30 to 39 (stem elongation or jointing stage) to zadoks scale 41 to 49 (booting stage), followed by zadoks scale 61 to 69 (flowering or anthesis) stage. Water use efficiency has increased chiefly due to less amount of water footprint recorded under micro-irrigation systems (16-33 % less) over surface irrigation. The level of water footprint saved in physical and monetary terms indicated that around 600 m³ha-¹ has been saved using seed priming which reduced the irrigation cost (Table 2).

Table 1. Effect of seed priming at different moisture levels on yield of wheat (Pooled data of 4 years)

Treatments	Grain yield (kg ha-1)
A. Seeding Method	
M ₁ : Seeding at optimum moisture	5723
$\mathrm{M}_{\scriptscriptstyle{2}}\!\!:$ Seeding at sub-optimal soil moisture	5637
M ₃ : Seeding in dry soil followed by irrigation	5652
CD (5%)	NS
B. Seed Priming	
S_{1} : No seed priming	5416
S_2 : Seed priming	5767
S_3 : Sprouted seeds	5831
CD (5%)	206

Table 2. Effect of seed priming at different moisture levels on yield and water use efficiency of wheat (Pooled data of 4 years)

Treatment	Grain yield in kg ha ⁻¹	Grain yield in kg ha ⁻¹	Water use efficiency (kg.m ⁻³)
M_1S_1	5460	4650	1.19
$\mathbf{M}_{_{1}}\mathbf{S}_{_{2}}$	5749	4650	1.26
M_1S_3	5962	4650	1.31
M_2S_1	5404	4275	1.29
M_2S_2	5713	4275	1.37
M_2S_3	5792	4275	1.39
M_3S_1	5383	4275	1.29
M_3S_2	5837	4275	1.41
M_3S_3	5736	4275	1.38
CD (5%)	175		

Where, M_1 , Seeding at optimum moisture level; M_2 , seeding at sub-optimal soil moisture level; M_3 , seeding in dry soil followed by irrigation and S_1 , no seed priming; S_2 , seed priming; S_3 , serouted seeds

Cost reduction comprises the savings in cost of irrigated water, labour cost as well as charges on electricity. The cost of irrigation was lowest in treatment where seeding was done under sub-optimal moisture level since one irrigation has been foregone (600 m³ha-¹) relative to the conventional practice. Among the micro irrigation techniques, water footprint saved was highest in drip followed by sprinkler and drip+rainport. The cost remained low in comparison to surface method of irrigation (check basin) due to less water and labour requirement. The net savings under micro irrigation was higher for drip and sprinkler, followed by drip+rainport (Fig 1).

On the basis of four years study, it is concluded that primed and sprouted seeds may be practiced to enhance the crop establishment, growth and yield of wheat under moisture stress conditions. Poor establishment of crop due to delayed sowing and lack of optimum soil moisture is a major constraint in areas where intensive cropping systems are in practice. Further, priming and sprouted seeds are simple to adopt and cost effective. Proper crop establishment increase the competitiveness against weeds and tolerance to other abiotic stress (Clark et al., 2001). In addition, this technique helps in advancing the wheat sowing by about 10-15 days as well as avoiding the pre-sowing irrigation. Under ricewheat system, this technique is highly recommended for utilizing the residual soil moisture after rice harvest, saving crop duration time, sacrificing one irrigation along with yield enhancement followed by other supplementary agronomic and economic benefits. Similarly, proper water management through micro irrigation helps the crop in quick utilization of the available nutrients resulting in higher growth and yield of wheat as compared to surface method of irrigation. Micro irrigation increases the yield potential by producing a congenial environment resulting in higher assimilation of plant nutrients apart from increasing the root absorption capacity (Hao et al., 2008). The technique facilitates to sacrifice the water footprint by 31% which is made possible through maintaining the available soil moisture at low water tension throughout growth period (Patel et al., 2006). Further, it supply water to the crop matching its evapo-transpiration demand and provide optimum soil moisture at critical growth stages resulting in improved water use efficiency (Kipkorir et al., 2002).

Altogether, the study recommends the micro irrigation systems coupled with seed priming practise for higher wheat and water productivity.

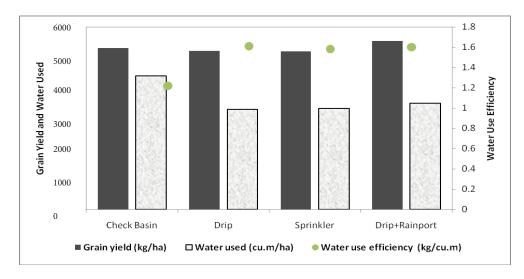


Fig. 1 Effect of micro irrigation on wheat yield, water used and productivity

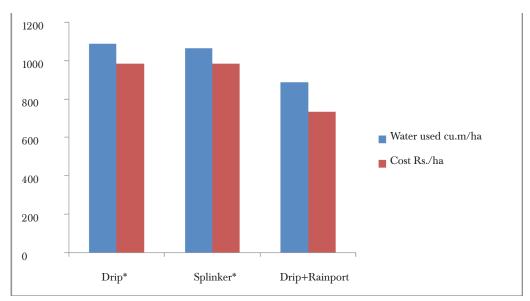


Fig. 2 Water savings and cost of water savings under different techniques against conventional practices

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