Effect of hydrogel on the performance of aerobic rice sown under different techniques

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ABSTRACT

Declining water is a great concern in production of rice, because rice is more sensitive to water deficiency which restricts normal rice growth resulting in enormous economic loss. A field experiment was conducted to study the effect of hydrogel in different sowing techniques of aerobic rice viz. flat, ridge, and bed sowing. Observations on soil moisture percentage before every irrigation, yield, and yield components of rice were recorded. Application of hydrogel improved soil moisture contents in all the three sowing techniques as compared to soil without hydrogel. More soil moisture contents met the crop water needs and increased the number of germinated seeds. As a consequence of more emergence and better stand establishment, the yield components were also improved increasing the yield of rice in hydrogel amended soil in all sowing techniques. However, sowing of rice on beds with hydrogel amendment was found the most effective; it not only improved the performance of aerobic rice but also enhanced growth and yield of aerobic rice more than other sowing techniques.

Keywords: soil moisture; seed emergence; yield; yield components, water absorbent

Irrigation water is becoming scarce and the world is looking for water-efficient agriculture. Increasing food demand and declining water resources are challenges for food security (Kreye et al. 2009). With decreasing water availability, rice production is needed to be switched towards water saving production systems. In the system of aerobic rice, especially adapted aerobic rice cultivars are grown under non-flooded or aerobic soils with supplementary irrigation (Bouman 2001, Bouman et al. 2005). Growing rice aerobically saves a significant amount of water which can be used for any other purpose. Although aerobic rice has a great potential for saving water but all this is at the cost of severe reduction in yield. A less water availability at reproductive stage is found to be a reason for low yield of aerobic rice (Bouman et al. 2002). It is, therefore, obligatory to develop appropriate management strategies in order to make water available to maximize the income on sustainable basis. Aerobic rice is emerging water saving rice production system in which rice is grown like wheat or maize. However, with low available water there is a contradiction among researchers which of different sowing techniques is better. For example, Tong-Chao et al. (2007) and Jin et al. (2007) have a view that shifting rice from flat to beds increases the water use efficiency of rice resulting in yield improvement, while Humphreys et al. (2005) and Stathakos and Gemtos (2002) concluded that flat and ridge sowing techniques improved better than others.

Hydrogel is a synthetic polymer, which is able to absorb and hold 80–180 times its volume of water for a long time (Wang and Gregg 1990). Hydrogel acts as a reservoir to store and release a steady stream of water and nutrients which plants need to grow. Plant roots are able to absorb water from the crystal bead of hydrogel. Several previous studies showed that these are very useful under limited water conditions to cope with plant water needs (Henderson and Hensley 1985, Ingram and Yeager 1987, Wang and Gregg 1990). Johnson (1984) reported that addition of hydrogel at the rate of 2 g/kg improved the water holding capacity of sand from 171% to 402%. Application of hydrogel decreases the irrigation requirements of several crops by improving water holding capacity resulting in delay and onset of permanent wilting percentages under intense evaporation. An increase in water holding capacity due to hydrogel amendment significantly reduced the irrigation requirement of many plants (Taylor and Halfacre 1986).

As different growing techniques may be used to grow rice with less water, it is important to find out the best one. Furthermore, much work is done on hydrogel in different crops but little is known with regard to the thirstiest rice. The present study was done with the hypothesis that application of hydrogel in different rice sowing techniques will increase the efficiency of these to improve the water status of the soil. The objective of the study was to determine the effect of hydrogel on yield and yield components of aerobic rice with the best sowing technique.

MATERIALS AND METHODS

Experimental site and soil characteristics. The present study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (31°26'N, 73°06'E), during Kharif 2009. The experiment was conducted in a sandy loam soil (75% sand, 12% silt and 13% clay). Common soil characteristics were C_{org} 0.5%; N_{tot} 0.043%; P_{Olsen} 1.00 ppm; K_{ext} 187 ppm; Zn_{DTPA} 1.54 ppm and Fe_{DTPA} 4.47 ppm. The experiment was laid out in randomized complete block design with factorial arrangement having three replications and net plot size of 3.0 m × 7.0 m. The hydrogel was randomized in main plots and sowing methods in subplots.

Sowing techniques and hydrogel application. Sowing techniques comprised flat sowing, ridge sowing and bed sowing. Hydrogel was applied manually at the time of soil preparation at 2.5 kg/ha. The material used as hydrogel was carbonyl amide polymer 25%. There were two hydrogel treatments i.e. control and application of carbonyl amide polymer 25%. Fine rice variety Super Basmati was used as medium of trial with seed rate of 75 kg/ha. The rice crop was sown with a single row hand drill in lines at 30 cm spaced rows; while on ridges, seeds were planted on one side maintaining line to line distance 30 cm. In beds, planting was done on both sides with the same line-to-line distance, sowing was done in aerobic conditions and irrigation was applied just after the sowing of rice seed. The crop was sown on July 16, 2009.

Crop husbandry. Giving one deep ploughing with disc plough followed by cultivation and planking twice prepared the experimental field. Recommended dose of fertilizer (133–85–62 kg NPK/ha) was applied in the form of urea, di-ammonium phosphate and potassium sulphate. All the P, K, and half of N were applied before sowing, and the second half of N was applied at panicle initiation stage, while 12 kg Zn/ha was applied in the form of zinc sulphate (Zn 35%) after 15 days of sowing.

The crop was irrigated at seven-day intervals to maintain moist field conditions. Irrigation was withheld about two weeks before harvesting when the signs of physiological maturity appeared. All other agronomic practices were kept normal and uniform for all the treatments. Harvesting was done manually in the first week of November 2009, when panicles were fully ripened and threshing of crop from each plot was done separately.

Soil moisture contents. Soil moisture contents were measured before giving irrigation to the crop. Samples were collected at 0–15 cm depth and moisture percentage was measured using gravimetric method.

Yield and yield components. Number of germinated seeds was counted from an area of 100 cm × 100 cm from three different places in each plot as to calculate the average number of germinated seeds per m^2. All other parameters were measured and observed following standard procedures.

Statistical analysis. The collected data were analyzed statistically using Fisher's analysis of variance technique and treatment means showing significant *F*-values were compared by the least significant difference (*LSD*) test at 5% probability level (Steel et al. 1997).

RESULTS

Soil moisture contents. A considerable variation in soil moisture content among all experimental treatments was observed (Table 1). Application of hydrogel improved the moisture contents of soil in all sowing techniques. Among three sowing techniques, a range of maximum soil moisture percentage 13.53–14.63% was observed in bed sowing and hydrogel improved the efficiency of this sowing technique to retain moisture for longer time. Flat sowing of rice without hydrogel application retained minimum soil moisture in the upper 0–15 cm soil depth and it ranged between 9.88 and 11.15% throughout the growing period of the crop.

Emergence count. More seeds were germinated (185.56) in plots treated with hydrogel as compared to non-treated plots (158.01) (Table 2). However, sowing methods did not affect significantly the emergence of rice seeds. Although in ridge sown crop more emergence count (180) of rice seeds was measured than at flat sowing (172) and bed sowing (162), the difference could not reach to the level of significance.

Table 1. Effect of hydrogel on soil moisture content (%) in different sowing techniques of aerobic rice (soil depth of 0–15 cm)

Treatments	Soil moisture percentage at different stages of crop								Average
	21 DAS	28 DAS	35 DAS	42 DAS	53 DAS	60 DAS	77 DAS	84 DAS	
No hydrogel									
Flat sowing	9.88	11.15	10.09	10.30	10.45	10.44	9.59	10.03	10.24
Ridge sowing	11.37	11.32	9.95	10.06	9.65	9.72	10.23	10.26	10.32
Bed sowing	10.82	11.43	10.18	10.88	9.87	10.01	9.54	10.07	10.35
Hydrogel (2.5 kg/ha)									
Flat sowing	12.78	13.20	12.21	12.87	11.03	13.10	12.83	13.31	12.67
Ridge sowing	12.60	13.56	12.99	13.35	12.45	13.10	12.50	12.14	12.84
Bed sowing	14.11	14.63	14.54	13.63	13.55	14.43	14.29	14.42	14.20

DAS – days after sowing

Yield and yield components. Application of hydrogel significantly improved plant height at maturity (84.33 cm) (Table 3). Similarly significant variation in plant height of rice was observed under different sowing techniques. Maximum plant height (84.00 cm) of rice was measured in bed planting compared to the minimum plant height (71.83 cm) in flat sowing. A similar trend was observed in case of number of fertile tillers that was improved by hydrogel application (Table 3). There was a significant difference in number of kernels per panicle of rice between hydrogel treated and non-treated soil plots (Table 3). Maximum number of kernels per panicle (70.70) was observed in bed sowing treated with hydrogel and was at par with hydrogel treated ridges (69.80). In general, hydrogel improved kernel per panicle in all sowing techniques. Hydrogel application also improved 1000-kernel weight of rice crop. Rice crop sown on beds produced bold grains with higher test weight 17.45 g, while minimum (16.91 g) 1000-kernel weight was recorded in flat sowing (Table 3). As a consequence of improvement in all the yield contributors, hydrogel significantly increased the kernel yield of rice (2.39 t/ha) as compared to no hydrogel (2.25 t/ha). Hydrogel application in bed sowing technique gave maximum kernel yield of rice (2.46 t/ha) followed by ridge sowing (2.37 t/ha) in hydrogel treated soil. In short, the application of hydrogel improved the efficiency of all sowing techniques but a combination of hydrogel with bed sowing improved the aerobic rice culture most.

DISCUSSION

Water uptake is the first important event after sowing of seeds in the soil. A soil with optimum moisture contents is a good medium for seeds to germinate. Poor soil moisture level is often found the important reason causing destitution of crop establishment. Higher soil moisture content in soil with hydrogel was observed. The results of the present study strongly agree with the previous work done by Akhter et al. (2004) that the hydrogel addition in soil was effective in improving soil moisture availability and thus increased plant establishment. It is well documented that the addition of gel-polymers has the potential to improve plant vegetative growth by retaining more moisture contents (Choudhary et al. 1995, Al-Harbi et al. 1999). Johnson (1984) and Huttermann et al. (1999) reported that the addition of gel-polymer to sandy soil could change the water-holding capacity to be comparable to that of silty clay or loam soils.

Increased moisture contents resulted in high number of germinated seeds in soils with hydrogel amendment in all three sowing techniques. The

Table 2. Effect of hydrogel on emergence count in different sowing techniques of aerobic rice

Sowing methods	No hydrogel	Hydrogel (2.5 kg/ha)	Mean
Flat sowing	145.50	180.00	162.75
Ridge sowing	173.67	186.67	180.17
Bed sowing	154.87	190.00	172.43
Mean	158.01^{B}	185.56^{A}	

Any two means not sharing a common letter differ significantly at $P \leq 5\%$ level

Table 3. Effect of hydrogel on yield and yield components in different sowing techniques of aerobic rice

	No hydrogel	Hydrogel (2.5 kg/ha)	Mean
Plant height (cm)			
Flat sowing	64.66	79.00	71.83^{c}
Ridge sowing	71.33	83.66	77.50^{b}
Bed sowing	77.66	90.33	84.00^{a}
Mean	71.22^{B}	84.33^{A}	
Number of fertile tillers (1/m^2)			
Flat sowing	245.00	264.67	252.11^{b}
Ridge sowing	253.67	268.67	261.17^{ab}
Bed sowing	257.67	273.00	265.33^{a}
Mean	252.11^{B}	268.78^{A}	
Number of kernels per panicle			
Flat sowing	62.56^{e}	69.06^{b}	65.81^{c}
Ridge sowing	65.70^{d}	69.80^{ab}	67.75^{b}
Bed sowing	67.80^{c}	70.70^{a}	69.25^{a}
Mean	65.35^{B}	69.85^{A}	
1000 kernel weight (g)			
Flat sowing	16.66	17.16	16.91^{c}
Ridge sowing	17.06	17.36	17.21^{b}
Bed sowing	17.26	17.63	17.45^{a}
Mean	17.00^{B}	17.38^{A}	
Kernel Yield (t/ha)			
Flat sowing	2.21^{f}	2.33^{c}	2.27^{c}
Ridge sowing	2.25^{e}	2.37^{b}	2.31^{b}
Bed sowing	2.29^{d}	2.46^{a}	2.37^{a}
Mean	2.25^{B}	2.39^{A}	

Means followed by different letters (lower case) in a column differ significantly at $P \leq 5\%$ level. The different letters (capital) following mean values indicate significant differences between hydrogel treatments

findings of the study are supported by the earlier work done by Woodhouse and Johnson (1991) who also reported the improved emergence rate and percentage by soil treated with hydrogel. Yang et al. (2008) studied a novel soil stabilizer based on poly-amino acid polyaspartic acid (PASP) and its copolymer which was modified with xanthan gum (XG) and concluded that the polymer had a positive influence on seed emergence and growth. Our results are contradictory with some researchers who found no effect of soil amendment with hydrogel on emergence and early seedling growth in different species (Ingram and Yeager 1987, Akhter et al. 2004).

Employing water absorbent not only enhanced the crop stand establishment but kernel yield of paddy was also improved. Hydrogel treatment of soil gives more paddy yield as compared to non-treated soil; due to higher emergence and better crop establishment it seems a result of moisture supply. Application of hydrogel significantly improved all the yield components i.e. plant height, number of fertile tillers (1/m^2), number of kernels per panicle and 1000 kernel weight (g); and as a result higher kernel yield was obtained. Our findings are in line with those reported by Yezdani et al. (2007) who obtained more yield of soybean by hydrogel application in drought-prone soils. Bhardwaj et al. (2007) used water absorbents in sandy soils from arid and semiarid regions and reported as an important tool in increasing water use efficiency and crop production. The results of present study match with the findings of Hayat and Ali (2004) who stated that absorption of water by synthetic polymer and its effect on yield parameters helps to increase the yield of crops. It was also confirmed by the work of Madiwalar and Prabhakar (1998). The results of sowing methods confirm the earlier work done by Mobley and Albers (1993). They showed that bed sowing exhibited more vigorous early season growth with taller plants, better main stem node development and more total biomass.

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