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Research Paper

Integrated moisture stress management in wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 2010–11 and 2011–12 at Hisar, Haryana, to study integrated moisture stress management in wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.]. The treatments consisted of 4 moisture regimes in main plots, viz. irrigation at crown-root initiation (CRI) + 100 mm cumulative pan evaporation (CPE), CRI + 150 mm CPE, CRI + 200 mm CPE and CRI only, and 6 moisture-stress management practices in sub plots, viz. no moisture stress-management, seed hardening (SH) by $CaCl_2$, SH + KCl spray, SH + mycorrhizae application + KCl spray, SH + mycorrhizae + KCl spray + kaolin spray and Pusa hydrogel application. Significantly the highest plant height, numbers of tillers, leaf-area index, leaf-area duration, dry-matter accumulation and crop growth rate were recorded with irrigation at CRI + 100 mm CPE over irrigation at CRI only. Similarly significantly highest grain yield, straw yield, harvest index, spikes/m^2, spike length, spikelets/spike, grains/spike, grain weight/spike, test weight and net returns were recorded with CRI + 100 mm CPE over irrigation at CRI only. The treatment SH + mycorrhizae + KCl spray + kaolin spray recorded significantly highest plant height, numbers of tillers, leaf-area index, leaf-area duration, dry-matter accumulation, crop-growth rate, spikes/m^2, spike length, spikelets/spike, grains/spike, grain weight/spike and test weight over irrigation at CRI only. Significantly the highest grain and straw yields, as well as net returns were recorded in SH + mycorrhizae + KCl spray + kaolin spray over irrigation at CRI only.

Key words : Antitranspirant, KCl, Moisture regime, Mycorrhizae, Pusa hydrogel, Seed hardening

Drought is a climatic anomaly, characterized by deficient supply of moisture resulting either from sub-normal rainfall, erratic rainfall distribution, higher water need or a combination of all the factors. Moisture stress affects the wheat productivity and also the efficiency of other inputs.

Various drought-management practices have been developed to cope up with the moisture stress and to increase the crop yield per unit amount of water used. Seed hardening has been reported to induce drought resistance in plants and enhances the capacity of seeds to withstand dehydration and overheating. The arbuscular mycorrhizae are fungi that colonize roots of a large number of plant species, enhancing host drought resistance, modifying soil-plants water relations and increasing water absorption capacity (Subramanian and Charert, 1998). Potassium plays vital role under moisture-stress condition by stimulating biological process in the plant cell such as enzymes activation, photosynthesis, chlorophyll synthesis, carbohydrate formation, water balance in leaves and regulation of stomata opening (Mesbah, 2009). Spraying antitranspirant results in higher relative water content, water-use efficiency in association with lower rate of water use per day and consumptive use which contribute for higher crop yield (Mishra, 1996).

There is an urgent need to concentrate the work on how best the productivity of wheat under moisture-stress conditions can be enhanced by suitable ameliorative measures. There are certain avenues to improve the productivity of wheat under soil-moisture stress condition like seed hardening, mycorrhizae application, Pusa hydrogel, KCl spray and antitranspirant spray to induce drought tolerance in crop plants. But, the study on integrating these aspects in managing the moisture stress is very meager and therefore there is an urgent need to improve the productivity of wheat under receding soil moisture conditions by integrating these moisture-stress management practices. In this view, the present investigation was undertaken to study the effect of integrated moisture-stress management practices on growth and yield of wheat.

MATERIALS AND METHODS

The field experiment was conducted at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar,

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(29°10' N, 75°46' E, and 215.2 m above mean sea level) during the winter (*rabi*) seasons of 2010–11 and 2011–12. The experiment consists of 4 moisture regimes, viz. CRI (irrigation at crown root initiation) + 100 mm CPE (cumulative pan evaporation), CRI + 150 mm CPE, CRI + 200 mm CPE and irrigation at CRI only as main plots. It also consisted of 6 moisture-stress management practices, viz. no moisture stress management, seed hardening (SH) by $CaCl_2$, SH + KCl spray at 90 days after sowing (DAS), SH + mycorrhizae application at sowing + KCl spray at 90 DAS, SH + mycorrhizae + KCl spray + Kaolin spray at 115 DAS and Pusa hydrogel at sowing, as subplots. The experiment was laid out in split-plot design with 3 replications. The wheat variety 'WH 1025' was sown on 5 December in 2010 and 8 December in 2011. Sowing was done at a spacing of 20 cm. The recommended doses of nitrogen (150 kg N/ha), phosphorus (60 kg P_2O_5/ha) and zinc sulphate (25 kg/ha) were applied.

The crop was sown with the presowing irrigation and remaining irrigations were given as per the treatment, i.e. S1 received 3 irrigations, S2 and S3 received 2 irrigations each and S4 received only one irrigation at CRI. The total rainfall received was 126.1 mm during the first year of wheat crop and in second year it was 47.7 mm. The growth and yield parameters were measured as for the standard procedure. Leaf area was recorded using leaf area meter (LI 3000 Area meter, LICOR Ltd. Nebroska, USA).

RESULTS AND DISCUSSION

Growth parameters

The pooled data of both the years revealed that the irrigation application at CRI + 100 mm CPE recorded significantly higher plant height, number of tillers, leaf-area index, leaf-area duration, total dry matter accumulation and crop-growth rate over irrigation at CRI only. Among other factors that control the crop growth and yield, water and temperature plays an important role in affecting the internal processes, which are governed by the environment. Thus, the microclimate to some extent can be manipulated by proper agronomic practices for achieving higher production. Higher amount of dry-matter accumulation in leaves helped the photosynthetic area to remain active for longer period and is responsible for overall better performance of plant under moisture-stress condition. Significantly highest leaf-area index and leaf-area duration were recorded with CRI + 100 mm CPE followed by CRI + 150 mm CPE moisture regime compared to rest of the treatments, which clearly indicated the superiority of CRI + 100 mm CPE moisture regime to the other treatments. The decline in leaf-area index and leaf-area duration in CRI + 200 mm CPE and irrigation at CRI treatments may be due to moisture stress and nutrient depletion from leaf at reproductive stage and which caused leaf senescence.

Among the different moisture-stress management practices significantly higher plant height, number of tillers, leaf-area index, leaf-area duration, total dry-matter accumulation and crop growth rate were recorded under SH + mycorrhizae + KCl spray + kaolin spray than no-moisture stress-management practices. The superior performance of SH + mycorrhizae + KCl spray + kaolin spray treatment may be attributed to integrated moisture-stress management practices involving application of mycorrhizae, which increased the soil-moisture availability, seed hardening with $CaCl_2$ helped early germination and quick establishment, spraying of KCl benefited crop by osmoregulation and by increasing nutrient availability and application of antitranspirant (kaolin) avoided excess evapotranspiration.

Pusa hydrogel helped in conserving soil moisture by retaining soil moisture in root zone. It absorbs more than 80 g of water/gram of the xerogel (dry polymer) and therefore is termed as superabsorbent hydrogels (http://pusahydrogel.com/index.html, 2013). The main reason for reduction in leaf-area index and leaf-area duration in treatment involving no management practices is due to less crop growth, dry-matter accumulation in leaf, leaf expansion and less moisture maintenance in root zone and also increase in leaf senescence compared to moisture-stress management practices.

Yield attributes

The yield attributes, viz. spikes/m^2, spike length, spikelets/spike, grains/spike, grain weight/spike and test weight, were significantly highest under CRI + 100 mm CPE over the no management. The higher number of grains/spike, spikes/m^2 and test weight attributed to higher grain yield. The yield of any crop species depends on the source–sink relationship and is the cumulative function of various growth parameters and yield-attributing characters of sink, viz. number of effective tillers, spike length, spikelets/spike, grains/spike and test weight. Stronger source is required to develop stronger sink (Aadesh, 2013). Among moisture-stress-management practices, SH + mycorrhizae + KCl spray + kaolin spray recorded significantly highest yield attributes, viz. spikes/m^2, spike length, spikelets/spike, grains/spike, grain weight/spike and test weight, over on-management treatment. Ranjita (2007) obtained similar results and reported that kaolin contributed to enhanced yield-attributing characters and yield.

Yield

The wheat crop responded significantly in terms of grain yield to different moisture regimes. Grain yield was significantly higher with CRI + 100 mm CPE moisture regime over irrigation at CRI only and was on a par with CRI + 150 mm CPE (Table 2). The increase of grain yield in CRI + 100 mm CPE and CRI + 150 mm CPE moisture regimes was of the order 20.14 and 18.23%, respectively, over irrigation at CRI only. The higher grain yield observed under CRI + 100 mm CPE and CRI + 150 mm CPE moisture regime may be due to 2 and 1 extra irrigations received by these treatments respectively. The time of irrigation also benefited crops for producing higher yield as in treatment CRI + 100 mm CPE the time of irrigation coincided with the heading and milking stage and in treatment CRI + 150 mm CPE coincided with anthesis stage of wheat. These stages being critical for scheduling irrigation benefited wheat crop by getting adequate moisture at right time and is reflected in better performance of growth, physiological, yield parameters and grain yield. The lower level of yield in treatment irrigation at CRI only was due to scarcity of soil moisture, as it received 1 irrigations only at crown-root initiation and it did not receive irrigation there after at critical stages and any moisture stress at these critical stages cause maximum yield reduction (Pal *et al.,* 1996) by reducing the yield components. The present findings are in accordance with the findings of Coventry *et al.* (2011) and Idnani and Kumar (2012).

The treatment SH + mycorrhizae + KCl spray + kaolin spray recorded significantly highest grain yield over no management (Table 2) and it was 20.8% higher over no management. Moisture-stress-management practices also contributed to enhanced yield-attributing characters, viz. dry-matter accumulation in spikes, spikes/m^2, spike length, spikelets/spike, grains/spike, grain weight/spike and test weight (g), which ultimately resulted in increased yield. This may be attributed to integrated moisture-stress management practices involving seed hardening with $CaCl_2$, application of mycorrhizae, spraying of KCl and application of antitranspirant (kaolin). Chikkappaiah (2010) revealed that the increase in seed yield was significantly more in treatment involving seed hardening.

Huixing Song (2005) revealed that the vesicular arbuscular mycorrhizae (VAM) were able to alter water relation of its host plants. Mechanism that VAM can enhance resistance of drought stress in host plant may include many possible aspects: (i) VAM improves the properties of soil in rhizosphere; (ii) VAM enlarges root areas of host

Table 1. Growth parameters of wheat as influenced by moisture regimes and integrated moisture-stress management practices (pooled data of 2010–11 and 2011–12)

Treatment	Plant height (cm) at maturity	Tillers/m^2 at 120 DAS	Leaf-area index at 120 DAS	Leaf-area duration at 90-120 DAS	Dry-matter accumulation (g / m^2) at 120 DAS	Crop-growth rate 120 DAS–maturity (CGR, g/m^2/day)
Moisture regimes (Irrigation at)						
S_1, CRI + 100 mm CPE	97	673	0.98	76	1485	2.04
S_2, CRI + 150 mm CPE	94	661	0.84	68	1446	1.78
S_3, CRI + 200 mm CPE	92	645	0.68	64	1410	1.29
S_4, CRI	90	629	0.51	59	1635	.05
SEm±	1.0	4.2	0.01	0.9	2.7	0.14
CD (P=0.05)	3.4	14.4	0.04	3.3	9.3	0.48
Moisture stress management						
M_1, No moisture stress management	88	617	0.52	46	1315	0.98
M_2, Seed hardening (SH) by $CaCl_2$	92	645	0.68	61	1406	1.42
M_3, SH + KCl spray at 90 DAS	95	658	0.77	68	1439	1.54
M_4, SH + Mycorrhizae application at sowing + KCl spray at 90 DAS	97	670	0.91	82	1492	2.00
M_5, SH + Mycorrhizae + KCl spray + Kaolin spray at 115 DAS	99	687	1.03	89	1525	2.15
M_6, Pusa hydrogel at sowing	90	635	0.61	56	1381	1.17
SEm±	0.8	8.3	0.02	1.4	4.81	0.19
CD (P=0.05)	2.4	23.5	0.05	4.0	2.5	0.55

DAS, Days after sowing; CRI, crown root initiation; CPE, cumulative pan evaporation plants, and improves its efficiency of water absorption; (iii) VAM enhances the absorption of P and other nutritional elements, and then improves nutritional status of host plant; (iv) VAM activates defense system of host plant quickly; (v) VAM protects against oxidative damage generated by drought; (6) VAM affects the expression of genetic material.

Spraying of antitranspirant results in higher relative water content and water-use efficiency in association with lower rate of water use per day and consumptive use which enhance crop yield (Mishra, 1996). Potassium plays vital role under moisture-stress condition by stimulating biological process in the plant cell such as enzymes activation, respiration, photosynthesis, chlorophyll synthesis, carbohydrate formation, water balance in leaves and regulate stomata opening as well as direct effect on the disease

Table 2. Effect of moisture regimes and integrated moisture-stress management practices on yield attributes, yield and harvest index of wheat (pooled data of 2010–11 and 2011–12)

Treatment	Spikes/m^2	Spike length (cm)	Spikelets/ spike	Grains/ spike	Grain-weight/ spike (g)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Moisture regimes (Irrigation at)									
S_1, CRI + 100 mm CPE	383	11	17	44	1.68	37	4.27	6.99	37.9
S_2, CRI + 150 mm CPE	351	10	16	43	1.62	35	4.17	6.91	37.6
S_3, CRI + 200 mm CPE	342	10	15	40	1.49	34	3.90	6.80	36.5
S_4, CRI	302	8	13	37	1.39	31	3.41	63.3	35.0
SEm±	6.0	0.26	0.20	0.49	0.02	0.24	0.04	0.06	0.31
CD (P=0.05)	21.0	0.90	0.68	1.71	0.08	0.83	0.15	0.21	1.06
Moisture stress management									
M_1, No moisture stress management	327	8	12	36	1.16	30	3.49	6.41	35.2
M_2, Seed hardening (SH) by $CaCl_2$	342	9	14	40	1.42	33	3.84	6.64	36.6
M_3, SH + KCl spray at 90 DAS	349	10	15	42	1.57	35	4.01	6.75	37.3
M_4, SH + Mycorrhizae application at sowing + KCl spray at 90 DAS	352	11	17	44	1.78	37	4.21	7.00	37.5
M_5, SH + Mycorrhizae + KCl spray + Kaolin spray at 115 DAS	359	13	18	45	2.00	38	4.41	7.15	38.1
M_6, Pusa hydrogel at sowing	338	9	13	39	1.34	33	3.69	6.61	35.8
SEm±	4.2	0.22	0.23	0.42	0.04	0.51	0.04	0.08	0.38
CD (P=0.05)	12.1	0.62	0.65	1.19	1.10	1.46	0.13	0.24	1.10

DAS, Days after sowing; CRI, crown root initiation; CPE, cumulative pan evaporation

Table 3. Effect of moisture regimes and moisture-stress-management practices on economics of wheat crop (₹/ha) (mean of 2010–11 and 2011–12)

Treatment	Gross Returns (×10^3 ₹/ha)	Cost of cultivation (×10^3 ₹/ha)	Net Returns (× 10^3 ₹/ha)	Benefit: cost ratio
Moisture regimes (irrigation at)				
S_1, CRI + 100 mm CPE	52.5	37.9	14.5	1.39
S_2, CRI + 150 mm CPE	51.3	37.1	14.1	1.37
S_3, CRI + 200 mm CPE	48.0	36.5	11.3	1.31
S_4, CRI	42.0	33.0	8.9	1.27
Moisture stress management				
M_1, No moisture stress management	42.8	35.2	7.7	1.22
M_2, Seed hardening (SH) by $CaCl_2$	47.1	36.1	10.9	1.31
M_3, SH + KCl spray at 90 DAS	49.2	37.1	12.1	1.33
M_4, SH + Mycorrhizae application at sowing + KCl spray at 90 DAS	51.6	38.2	13.4	1.35
M_5, SH + Mycorrhizae + KCl spray + Kaolin spray at 115 DAS	54.2	39.4	14.9	1.38
M_6, Pusa hydrogel at sowing	45.3	36.8	8.5	1.23

DAS, Days after sowing; CRI, crown root initiation; CPE, cumulative pan evaporation resistance (Mesbah, 2009). The KCl spray helped maintain higher water potential, as potassium plays important role in osmoregulation and thereby it increases osmotic potential of leaves, which causes reduction in loss of water from leaves. Similarly, the reason for better performance of Pusa hydrogel application was owing to improvement of soil hydro physical properties such as porosity, aggregate stability and hydraulic conductivity, absorption of minimum of 350 times of it's weight in pure water and gradually release to crop, improvement in seed germination and the rate of seedling emergence, improvement in root growth and density. Pusa hydrogel also helped the plants to withstand extended moisture stress, delays onset of permanent wilting point and reduction in irrigation and fertigation requirements of crops (http://pusahydrogel.com/index.html, 2013).

Economics

The highest net returns and benefit: cost ratio were obtained under CRI + 100 mm CPE moisture regime and lowest net returns under irrigation at CRI only (Table 3). Among the moisture-stress management practices, SH + mycorrhizae + KCl spray + kaolin spray recoded highest net returns and benefit: cost ratio and lowest net returns and benefit: cost ratio was obtained in no management. Our findings support the results of Ranjita (2007) and Aadesh (2013).

It is concluded that irrigation scheduling at crown-root initiation stage + cumulative pan evaporation of 100 mm CPE gave higher grain yield and net returns. The integrated moisture-stress management practices like seed hardening (SH) by $CaCl_2$ + KCl spray at 90 days after sowing (DAS) + mycorrhizae application at sowing + kaolin spray at 115 DAS gave higher grain yield and net returns.

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