POST-ANTHESIS DROUGHT MANAGEMENT IN LATE-SOWN WHEAT (*Triticum aestivum* L.)

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ABSTRACT

Post anthesis drought is common problem in late sown wheat, which reduces crop yield. A field experiment was conducted at Institute of Agriculture and Animal Science (IAAS), Rampur in 2005/06 to find out the effect of irrigation, seed rate and mulch on soil moisture content and productivity of late sown wheat. Irrigation applied at crown root initiation CRI and heading stage significantly increased moisture content at 80 days after sowing, grain filling period (GFP) and crop duration period (CDP), thousand grain weight, grain yield and harvest index. Higher seed rate was non significant on yield attributes and yield. Soil moisture content at 30, 80 and 95 days after sowing, vegetative growth period (VGP) and crop duration period, and grain yield were significantly higher in mulched plot than non mulched plot. Irrigation at reproductive stage and mulch were effective in increasing yield of late sown wheat.

Key words: Crop duration period, grain filling period, harvest index, Irrigation, mulch, vegetative growth period, Yield

INTRODUCTION

Rice-wheat system is a dominating cropping system of Nepal. Wheat, major winter cereal of the country, is sown generally after rice. The long duration rice variety takes longer time to vacate the field for normal sowing of wheat due to which farmers are compelled to plant wheat late. Late sown wheat encounter high temperature stress, high wind velocity and low relative humidity during the reproductive and grain filling stage (Pokharel 1996), which increase the evaporation rate and deplete soil water reserves (Viswanathan and Khanna-Chopra, 1996) and finally result in post-anthesis drought (Bland, 2001). Exponential growth of CO_2 and other greenhouse gases in the atmosphere is causing climate change. In Nepal a rise in temperature of 1.8^0 C from 1975 to 2006 has been recorded (Malla, 2008). Early rise in temperature after winter season and less rainfall during winter due to climate change also cause the Post –anthesis drought in wheat. Post-anthesis drought causes high tiller mortality, reduction in photosynthesis and duration of grain filling leading to shriveling of the grains and finally reduce grain yield (Siddique *et al.,* 1999).

Irrigation not only takes care of the deleterious effect of high temperature but also increase the input utilization efficiency of the crop (Dubey and Sharma, 1996). Mulching helps to decrease the soil temperature in summer and increase in winter (McCalla and Army, 1961), and delaying the formation of a hard soil crust.

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Late-sown wheat germinates less and growth is also checked due to lower temperature during late winter. Hence, the plant population per unit area of late sown wheat can be increased by increasing the seed rate which compensates for the reduced yield in late sown condition. Mahajan *et al.* (1991) mentioned that the yield attributes and grain yield of late-sown wheat were enhanced due to higher seed rates of 150 kg ha^{-1}. Information regarding post-anthesis drought management through the use of limited supply of soil moisture, increased plant population and mulch on late sown wheat is not sufficient.Therefore, the objectives of the present study were to find out the effects of irrigation, seed rate and rice-straw mulch on soil moisture content, yield attributes and yield of late-sown wheat.

MATERIALS AND METHODS

A field experiment was carried out during the winter season of 2005/06 at the Agronomy Farm of Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan. The experiment was laid out in a split-split design with 12 treatment combinations keeping three levels of irrigations(no Irrigation, Irrigation at CRI, Irrigation at CRI+ heading) in main plot, two levels of seed rates (120 kg ha^{-1}, 150 kg ha^{-1}kg/ha) in sub-plot and two levels of mulch (without and with) in sub-sub-plot and replicated thrice. The size of the sub-sub plot was 2.5 m x 3 m. There were 10 rows of wheat per plot at 0.25 m row spacing. The soil was sandy clay loam with poor fertility status.The fertilizers were applied @100:50:25 kg NPK ha^{-1} at the time of final land preparation. The variety BL-2217 was planted on 14th December, 2005.

The experimental site lies in the subtropical humid climatic zone. The rainfall received during the growth period of the crop was 3.10 mm. The mean maximum and minimum temperatures were 28.67^{0}C and 12.54^{0}C, respectively for the crop season. During the crop season, the maximum temperature ranged from 23^{0}C (January) to 34.83 ^{0}C (April). Similarly, the minimum temperature ranged from 8.04^{0}C (January) to 18.59^{0}C (November). The relative humidity ranged from 66.40 % in the month of April and 100 % in the month of December. Total water received from dew during initial four months (November to February) of the crop season was 25.94 mm.

Soil moisture was recorded at the regular interval of 10 days from 30 days after sowing (DAS) to maturity and determined by using gravimetric method. The vegetative growth period was recorded as the number of days from planting to anthesis and the grain filling period as determined as the number of days from anthesis to physiological maturity. A plant was assumed to be physiologically mature when approximately 75% of the glumes of the primary spike had turned yellow (Gebeyehou *et al.*, 1982). Biological yield, grain yield, yield attributing characters and floret sterility were recorded from the net plot during the time of harvest.

Harvest index (HI) was calculated as the per cent ratio of grain yield to the total biological yield i.e. total dry matter including grain yield. MSTAT-C package was used for the data analysis. Mean separation was done by using DMRT.

RESULTS AND DISCUSSIONS

SOIL MOISTURE CONTENT

Effects of irrigation

Soil moisture due to different numbers of irrigation did not differ significantly in the initial crop growth stage (30 to 70 DAS). The non significant effect of irrigation at early growth stage was due to availability of higher soil moisture because of foggy weather, dew, lower ambient temperature, less sunshine hours and high relative humidity, which reduced the atmospheric demand of water at early stages of crop growth. However, significantly higher soil moisture (17.12 %) was observed when irrigation was applied at CRI and heading stage than no irrigation (14.43 %) and remained similar with irrigation at CRI stage (15.54 %) at 80 DAS (Table 1). The irrigation applied at heading stage increased the soil moisture content in the irrigated plot as compared to non irrigated plot and as a consequence reduction in soil moisture in non irrigated plot resulted in post-anthesis drought.

Soil moisture status is a function of time for moisture treatment. Pannu and Singh (1993) observed increased soil water status with increased frequency of irrigation and it decreased slowly during crop season because water use exceeded the replenishment by irrigation.

Effect of seed rate

The moisture content decreased with an increase in the seed rate. The soil moisture content was lower with higher seed rate (150 kg ha^{-1}) as compared to the lower seed rate (120 kg ha^{-1}) at different growth stages except at 40 DAS (Table 1) but the effect was non significant. The lower soil moisture with the higher level of seed rate was due to higher number of tillers/m^2, which ultimately accelerated the loss of water through transpiration and finally led to low soil moisture content. Similar result was also obtained by Maliwal *et al.* (1995).

Effect of mulch

Mulch had significantly higher moisture content (21.38 %) as compared to no mulch (20.50 %) at early growth stage (30 DAS) and at later stages i.e. 80 and 95 DAS, while the effect of mulch on intermediate growth stages (40, 50, 60 and 70 DAS) remained unaffected. The higher soil moisture in mulched plot at later growth stage of the crop was due to retention of irrigated water applied at heading stage and reduction in evapo-transpiration (ET) from mulched plot. Yunusa *et al.* (1994) observed the significant reduction in ET (18 mm) under the mulched crop (wheat straw @ 8 Mg ha^{-1}) than no mulch crop in Western Australia. Furthermore, Mahey *et al.* (1986) reported that mulch changed the microclimate by conserving more moisture and modifying soil temperature. The soil moisture did not vary significantly because of mulch at 40-70 DAS. This was mainly due to the cooler weather and minimum evaporative demand at initial growth stage of the crop.

Table 1. Effect of irrigation, seed rate and rice-straw mulch on soil moisture status at different growth stages of late-sown wheat at IAAS, Rampur, Chitwan, Nepal during 2005/06

Treatment	Soil moisture content (%)						
	Days after sowing (DAS)						
	30	40	50	60	70	80	95
Irrigation							
No irrigation	21.22	21.55	21.03	20.87	19.26	14.43[b]	10.14
Irrigation at CRI	20.50	21.75	21.17	21.21	19.67	15.54[ab]	10.63
Irrigation at CRI + heading	21.10	21.76	21.35	21.44	19.70	17.12[a]	11.36
LSD	ns	ns	ns	ns	ns	1.893	ns
SEm ±	0.55	0.41	0.59	0.38	0.41	0.48	0.79
Seed rate							
120 kg ha^{-1}	20.75	21.80	21.40	21.29	19.65	15.75	11.08
150 kg ha^{-1}	21.13	21.57	20.96	21.06	19.44	15.64	10.34
LSD	ns	ns	ns	ns	ns	ns	ns
SEm ±	0.35	0.25	0.48	0.38	0.31	0.19	0.82
Mulching							
Without	20.50[b]	21.64	21.07	21.07	19.26	14.93[b]	9.91[b]
With	21.38[a]	21.73	21.29	21.28	19.83	16.46[a]	11.5[a]
LSD	0.55	ns	ns	ns	ns	0.89	1.38
SEm ±	0.18	0.19	0.19	0.27	0.37	0.29	0.45

Means followed by the common letter (s) within a column are not significantly different based on LSD at $P = 0.05$.

Interaction effects between seed rate and mulching

The interaction effects between seed rate and mulch treatment (Table 2) indicated that soil moisture content (21.98 %) was significantly higher from the combination of lower seed rate (120 kg ha^{-1}) and rice-straw mulch (5 Mg ha^{-1}) than the higher seed rate (150 kg ha^{-1}) without (20.71 %) and with mulch (20.78 %), lower seed rate without mulch (20.28 %) at 30 DAS. The higher soil moisture under lower seed rate and rice-straw mulch was attributed to the lower water use by lower plant population at early stage of the growth.

Vegetative growth period (VGP), grain filling period (GFP) and crop duration period (CDP)

Significantly higher grain filling period (28.25 days) was observed in Table 3. when irrigation was applied at CRI and heading stage than no irrigation (25.75 days) and remained at par with the irrigation at CRI stage (27.75 days). The percent increase in the grain filling period was 9.7 and 7.77 % due to irrigation at CRI and heading stage and irrigation at CRI stage over no irrigation, respectively. The increase in GFP from irrigated plot might be due to longer flag leaf duration as compared to no irrigation. It was found that longer the flag leaf duration, higher was the grain yield. Spiertz *et al.* (1971) found a positive correlation between length of GFP and grain yield in spring wheat cultivar. Longer GFP was associated with higher grain yield only in selected genotypes (Sharma, 1993).

Table 2. Interaction effect of seed rate and rice-straw mulch on soil moisture status during initial growth stage (30 DAS) of late-sown wheat at IAAS, Rampur, Nepal

	Soil moisture content (%) at 30 DAS	
Seed rate	Without mulch	With mulch
120 kg ha-1	20.28b	21.98a
150 kg ha-1	20.71b	20.78b
LSD	0.7775	
SEm ±	0.2523	

Means followed by the common letter (s) are not significantly different based on DMRT at *P* = 0.05.

Table 3. Effect of irrigation, seed rate and rice-straw mulch on vegetative growth period (VGP), Grain filling period (GFP) and crop duration period

Treatment	VGP	GFP	CDP
	Number of days		
vIrrigation			
No irrigation	70.33	25.75^{b}	96.08^{b}
Irrigation at CRI	70.00	27.75^{a}	97.75^{a}
Irrigation at CRI + heading	70.00	28.25^{a}	98.25^{a}
LSD	ns	1.03	1.51
SEm ±	0.34	0.26	0.39
Seed rate			
120 kg ha^{-1}	70.17	27.22	97.39
150 kg ha^{-1}	70.06	27.28	97.33
LSD	ns	ns	ns
SEm ±	0.24	0.26	0.38
Mulch			
Without	69.39^{b}	27.00	96.39^{b}
With	70.83^{a}	27.50	98.33^{a}
LSD	0.66	ns	0.98
SEm ±	0.22	0.24	0.32

Means followed by the same letter (s) within a column are not significantly different based on LSD at *P* = 0.05.

Crop duration (98.25 days) was observed significantly higher with the irrigation at CRI and heading stage than that of no irrigation (96.08 days) and remained similar to the irrigation at CRI (97.75). There was a positive correlation (r = 0.908) between GFP and soil-moisture content at 80 DAS. The effect of GFP and CDP were reflected on the grain yield (Table 4). The mulched crop showed significantly higher VGP (70.83 days) and CDP (98.33 days) than non mulched crop (69.39 and 96.39 days), respectively, while the effect of mulching was non significant on GFP.

Table 4. Effect of irrigation, seed rate and rice-straw mulch on yield attributes and yield of late sown wheat at IAAS, Rampur, Nepal 2005/06

Treatment	Effective tillers/m^2	Grains /spike	TGW (g)	Grain Yield ($Mg\ ha^{-1}$)	Straw Yield ($Mg\ ha^{-1}$)	HI (%)
Irrigation						
No irrigation	397.80	36.01	34.71^{b}	2.71^{b}	5.26^{a}	34.02^{b}
Irrigation at CRI	400.80	36.19	35.21^{ab}	2.78^{b}	5.09^{a}	35.30^{b}
Irrigation at CRI + heading	408.90	37.47	36.13^{a}	3.25^{a}	4.64^{b}	41.24^{a}
LSD	ns	ns	1.131	0.44	0.34	4.28
SEm ±	11.86	0.61	0.288	0.11	0.09	1.09
Seed rate						
120 kg ha^{-1}	394.90	36.51	36.14	2.89	4.88	37.19
150 kg ha^{-1}	410.10	36.61	34.56	2.93	5.11	36.52
LSD	ns	ns	ns	ns	ns	ns
SEm ±	6.930	0.36	0.69	0.09	0.10	1.13
Mulch						
Without	397.60	36.44	34.78	2.78^{b}	4.99	35.86
With	407.40	36.67	35.92	3.04^{a}	5.00	37.85
LSD	ns	ns	ns	0.17	ns	ns
SEm ±	4.52	0.45	0.66	0.06	0.12	0.8946

Means followed by the common letter (s) within a column are not significantly different based on LSD at $P = 0.05$.TGW= Thousand grain weight, TGW= Thousand grain weight

YIELD ATTRIBUTES

Effective tillers per square meter

Effective tillers did not differ significantly due to different levels of irrigation (Table 4). However, effective tillers increased due to increasing level of irrigations. The irrigation at CRI and heading stage might have facilitated the proper mobilization of soil nutrients as a consequence it resulted in higher effective tillers. Singh *et al.* (1991) also observed more effective tillers from two levels of irrigations (at tillering and flowering) than no irrigation. Similarly, Siddique et al. (1999) also found non-significant effect on effective tillers from watered plant.

Higher number of effective tillers was observed due to higher seed rate (150 kg ha^{-1}) as compared to lower seed rate (120 kg ha^{-1}) but the difference was not significant. The higher number of effective tillers m^{-2} under higher seed rate was because of the higher plant population m^{-2}. Upadhyay and Tiwari (1996) also observed the increasing numbers of effective tillers with the use of higher seed rate (150 kg ha^{-1}). The effective tillers per square meter increased in the mulch treated crop than non-mulched crop but the effect was non-significant.

Number of grains per spike Number of grains $spike^{-1}$ did not differ significantly from the increasing number of irrigations, seed rate and mulching. Although the more number of grain was associated with the irrigation at CRI and heading stage than no irrigation and irrigation at CRI (Table 4). Similarly, non significant effect of seed rate was also reported by Sarker and Torofder (1996).

Thousand grain weight (TGW)

Irrigation applied at CRI and heading stage significantly increased the TGW (36.13 g) as compared to no irrigation (34.71 g) but it was at par with irrigation at CRI stage (35.21 g). Irrigation given at CRI stage as well as at heading stage increased the availability of soil moisture at reproductive stage (Table 1). Higher availability of soil moisture at this stage increased the grain filling period and crop duration (Table 2). Increased grain filling period might have resulted in higher photosynthetic efficiency and deposition of more assimilates in grains. Thus, TGW was the highest when irrigation was applied at CRI and heading stage followed by irrigation at CRI stage and unirrigated plot. Upadhyaya and Dubey (1991) also found the significantly higher TGW due to more number of irrigations (four) as compared to single irrigation. TGW did not differ significantly from seed rates and mulching. Jain *et al.* (1991) and Sarker and Torofder (1992) also observed non significant differences in TGW due to seed rates.

GRAIN YIELD

Effect of irrigation

Grain yield was significantly influenced by different numbers of irrigation (Table 4). Higher grain yield (3.25 Mg ha^{-1}) was obtained with the irrigation at CRI and heading stage than no irrigation (2.71 Mg ha^{-1}) and irrigation at CRI stage (2.78 Mg ha^{-1}). Thakur *et al.* (2000) also found the increasing trend of grain yield with the increasing numbers of irrigation from two to four. Similar trend of grain yield was also reported by Rathore and Patel (1991).

The soil moisture content of unirrigated plot was very low at reproductive stage (Table 1). This situation led to water stress at reproductive stage. Irrigation given at CRI stage was also not sufficient to supply optimum soil moisture at reproductive stage. On the other hand, irrigation given at heading stage increased soil moisture content throughout the reproductive stage (Table 1). Optimum water availability at reproductive stage of plant has many effects on the rate and duration of grain growth such as carbon assimilation, nutrient uptake by roots, and cell division and expansion. Water availability is strongly correlated with kernel growth and grain yield (Johnson and Moss, 1976). Higher soil moisture content at reproductive stage increased the crop duration and grain filling period (Table 2). Furthermore, GFP was also positively correlated with grain yield ($r = 0.696$). Wiegand and Cuellar (1981) and Gebeyehou *et al.* (1982) also found the positive association between GFP and final grain weight.

Higher soil moisture content increased photosynthesis and accumulation of photosynthates. As a consequence, the overall effect was reflected on grain with higher TGW which ultimately resulted in increased grain yield of the crop due to irrigation at CRI and heading stage.

Furthermore, yield attributes viz. effective tillers m^{-2} and TGW were found higher with the two levels of irrigation, which were also responsible for the higher grain yield. The results corroborated the findings of Singh *et al*. (1991) and Upadhyaya and Dubey (1991).

Effect of seed rate

The effect of seed rate on grain yield remained unaffected. Sharma and Singh (1971) also found non significant effect of increased seed rate (150 kg ha^{-1}) on grain yield over lower seed rate (100 kg ha^{-1}).

Effect of mulch

Rice straw mulch showed the significantly higher grain yield (3.04 Mg ha^{-1}) over no mulch (2.78 Mg ha^{-1}). There was 9 % increase in grain yield from mulch treated crop as compared to no mulch. The higher grain yield under mulched crop was due higher availability of soil moisture during reproductive stage (Table 1) that enhanced CDP (Table 3) and ultimately resulted in higher grain yield. Upadhyay and Tiwari (1996) observed the increased in grain yield due to rice straw mulch as compared to saw dust mulch.

STRAW YIELD

Significantly higher straw yield was obtained due to no irrigation as compared to irrigation at CRI and heading stage and remained consistent with the irrigation at CRI stage (Table 4). Pal *et al*. (1996) found the higher straw yield with the increased levels of irrigation.

HARVEST INDEX (HI)

Crop irrigated at CRI and heading stage (Table 4) had significantly higher harvest index (41.24 %) followed by irrigation at CRI stage (35.30 %) and non irrigated treatment (34.02 %).Higher harvest index indicates better assimilate transport to the spikes.

CONCLUSIONS

The irrigation applied at CRI and heading stage increased the soil moisture availability throughout the reproductive stage minimizing the post-anthesis drought and that ultimately increased the grain filling period, test weight and grain yield. Mulching improved soil moisture availability to crop, increased crop duration and grain yield. Higher seed rate did not affect the yield attributes and grain yield.

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